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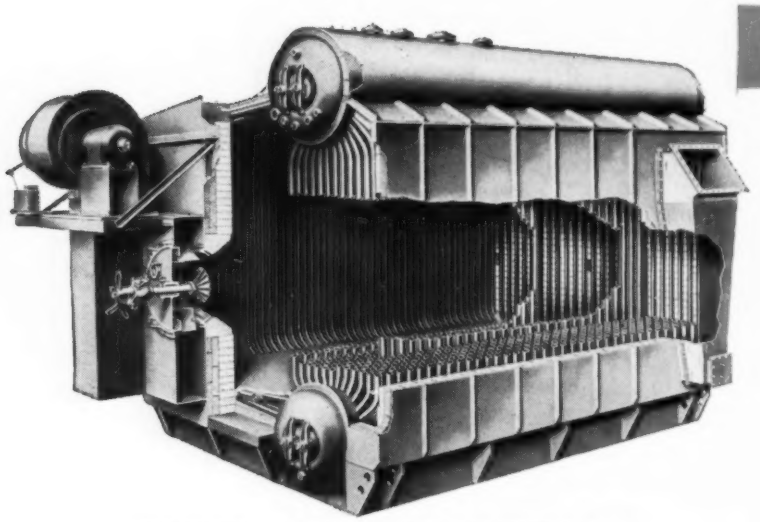

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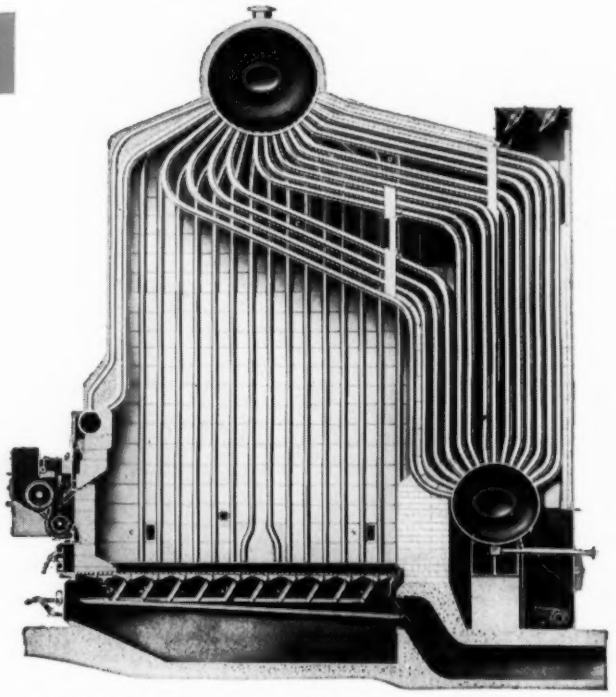

The VU-10 Boiler, as arranged for C-E Spreader Stoker firing

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ALL TYPES OF STEAM GENERATING, FUEL BURNING AND RELATED EQUIPMENT

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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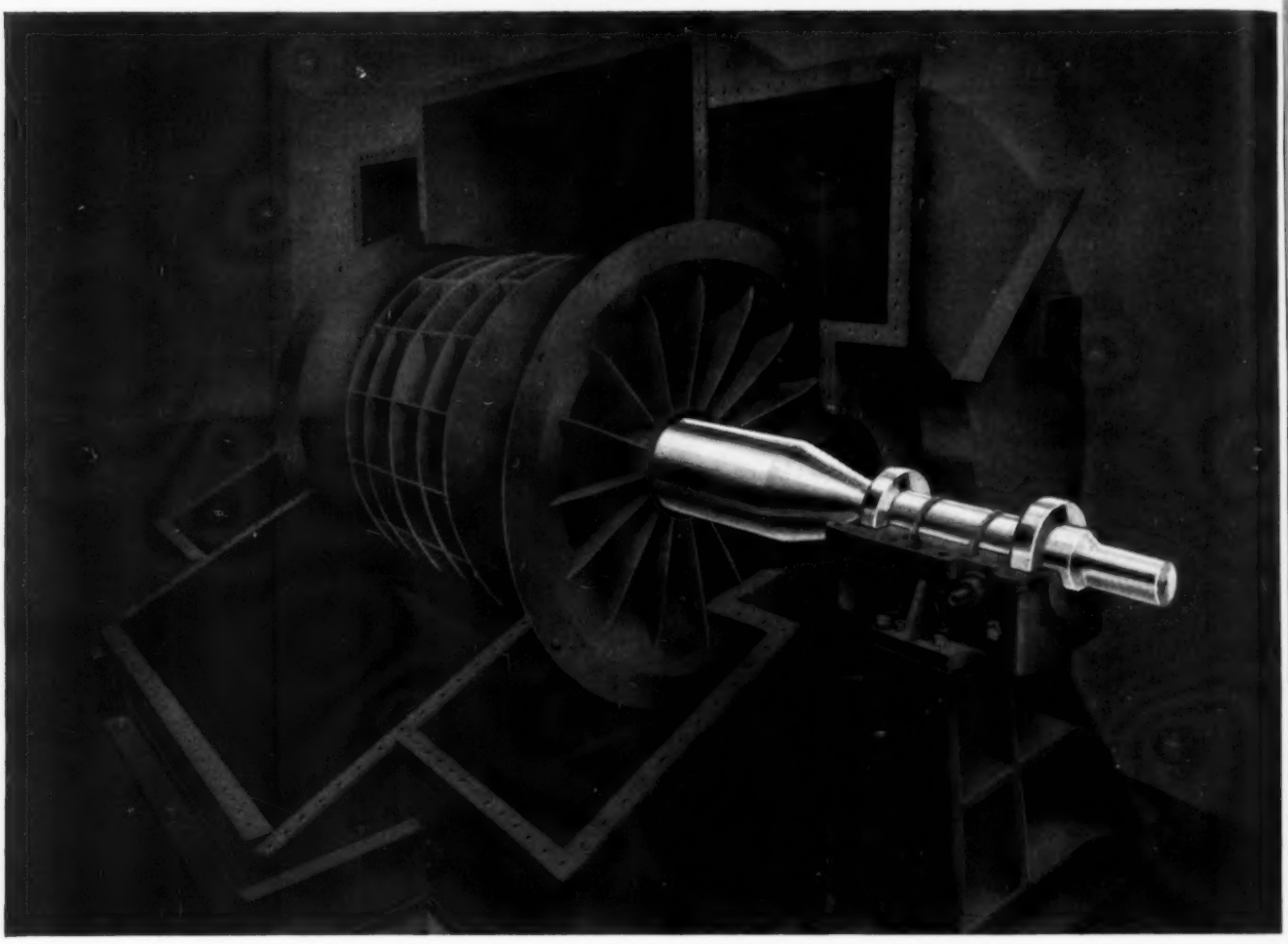

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Editorials

Amending the Atomic Energy Act

Recommendations made to Congress by President Eisenhower on February 18 to amend the Atomic Energy Act of 1946 are deserving of strong support. In his message the President noted the many changes that have taken place in the interim since 1946 and the desirability of having the government policy fit current requirements. While the United States no longer has a monopoly on atomic weapons, significant technological advances have been made in both the military and civilian applications of atomic energy. The legal framework under which the Atomic Energy Commission operates should be adapted to be in accord with present conditions.

The address made recommendations concerned with international cooperation, protection of atomic energy information and domestic development of atomic energy. While the power industry is indirectly affected by the first two categories of recommendations, its greatest interest naturally lies in peace-time applications of atomic energy. Commenting on this phase, the President made this statement:

"Before our scientists and engineers lie rich possibilities in the harnessing of atomic power. The Federal government can pioneer in its development. But, in this undertaking, the enterprise, initiative and competitive spirit of individuals and groups within our free economy are needed to assure the greatest efficiency and progress at the least cost to the public."

The President noted that a number of industrial corporations were already allocating funds to conduct studies of various reactor types but that these efforts could only be intensified if the way were open for private investment in reactors. To accomplish this he recommended that the law be amended to permit private industry to own and operate nuclear reactors, buy or lease fissionable materials, manufacture such materials, and obtain patents. The Atomic Energy Commission would continue to set safety and security regulations and would administer licensing systems. Patent provisions would be liberalized in a manner that would permit the holding of private patents but would prevent any patent monopoly at least for the next five years.

The outcome of Congressional deliberations on these proposed changes in the Atomic Energy Act will have a very pronounced effect upon the future course of atomic energy development. The recommendations of the President set the stage for much broader industrial participation and should have very strong support from all who believe that the free enterprise system offers the way to the most beneficial application of this important power resource.

The Future for Resources

As the world's leading industrial nation and one whose standard of living is the highest in recorded history we are properly concerned with the present and future status of all natural resources. Accordingly the findings of the Ford Foundation financed corporation, Resources for the Future, Inc., are of considerable interest.

Around the end of the year at Washington, D. C., this non-profit corporation sponsored a three-day Mid-Century Conference on Resources for the Future. This Conference ranged in its interests from crop lands and water availability to fuel and non-fuel mineral resources as well as a passing look at possible future energy sources.

Best future use of energy resources as they saw it depended upon the accuracy of fuel reserves data, fluctuations of the economy and possible substantial technological advances, especially in the development of atomic energy. Atomic power will constitute at most a rather small fraction of the U. S. power total in 1975. But by then, the conferees guess, atomic power will be an important factor in new construction. Further the Conference urged continued research on standard energy sources and on new ones, such as solar energy. The government's activity in bringing along alternate fossil fuels, oil shale especially, was favorably mentioned.

The 1700 experts in technical, economic and social aspects of resources came to the reassuring conclusion that the United States will not be a "have not" nation in 25 years. But the need is strong to continue (1) reviewing resources technology, (2) supporting research and education in fundamental problems, (3) establishing close cooperation between government and private industry, at all levels, if we are to get the most out of what we have and, at the same time, develop natural resources all over the world. All of this seems worthy of support.

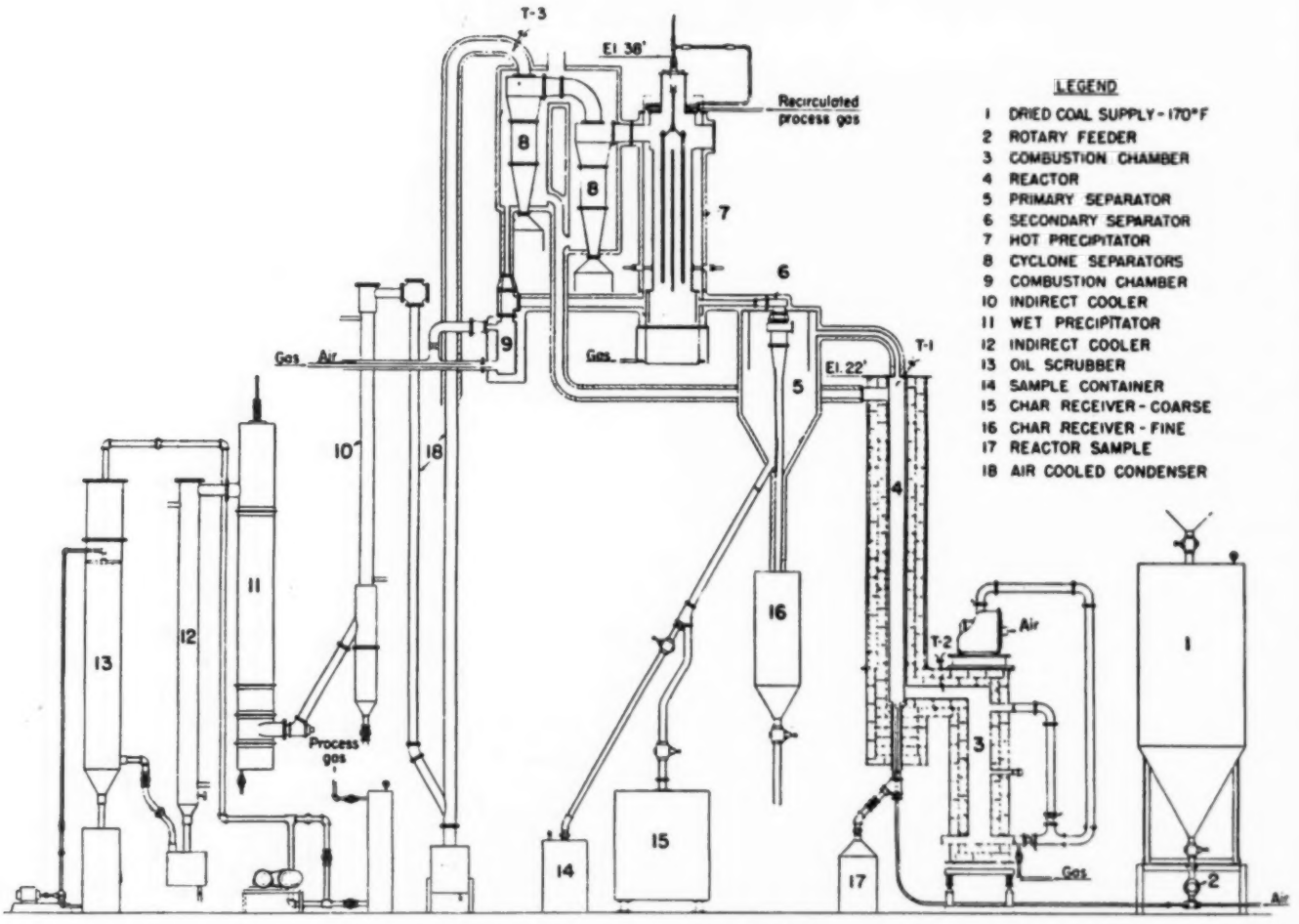

Fig. 1—Pilot plant takes dry lignite from storage at a temperature of 175 F and under pressure into a reactor where it reaches 1900 F at point T-2. All lignite dust, vapors, gases move out of the reactor to hot electrostatic precipitator.

Low Temperature Carbonization of

Lower rank coals below 14,000 Btu per lb lend themselves readily to low temperature carbonization in a fluidized state. But higher rank fuels, including lignite, show coking and agglomeration properties that make carbonization difficult. Here is some of the development work behind the attempt of Texas Power & Light Co. and the Aluminum Co. of America to use dried lignite and later char as direct fuels for power generation at Sandow power plant, abstracted from an AIChE paper.

By V. F. PARRY

U. S. Bureau of Mines

THE MAJOR industrial uses of char or semi-coke produced by low-temperature carbonization of coal or lignite, are as fuels for: (1) generation of electric power, (2) blending with metallurgical coking coal as a substitute for low-volatile coals, (3) gasification to produce synthesis gas for chemical purposes.

Low-temperature carbonization is a relatively simple processing step involving the heating of coal to about 900 to 1200 F to decompose the coal into four main products: semi-coke or char; complex, partly oxygenated, liquid hydrocarbons or tar; fixed gases; and water. If the heating is done rapidly under conditions which prevent decomposition of the primary products, 68 to 87 per cent of the net heat in the raw coal remains in the char and 10 to 23 per cent of the potential heat appears in the primary tar. Fixed gases represent approximately 7 per cent of the heat and approximately 2 per cent is lost or dissipated in the reactions of decomposition. Considering the different ranks of coal in the United States, the yield of tar will vary from about 9 to 44 gallons per ton. Therefore it is important that each coal be carefully considered if it is intended to be carbonized for industrial use.

If the coal is to produce a char for power-plant fuel, the value assigned to the char cannot be much greater

* Presented before the American Institute of Chemical Engineers, Annual Meeting, Dec. 1953. The full paper can only be obtained through this organization, 120 E. 41st St., New York, N. Y

Table 1 - Yields of primary products from low-temperature carbonization Assay of typical coals at 500°C.

Source	Penna.	Utah	Illinois	Wyoming	Wyoming	Texas	N. Dak.
Classification	HVAB	HVBB	HVBB	Sub. A	Sub. B	Lignite	Lignite
B.t.u. per lb. MAF [1/]	14,810	14,430	14,350	13,360	12,640	12,900	12,000
Oxygen, percent MAF	7.5	11.4	10.0	15.6	18.1	17.0	22.0
Analysis, percent							
Moisture	2.0	4.6	7.9	20.6	32.6	35.2	37.0
Volatile matter	41.3	44.4	32.1	35.5	28.7	28.2	27.0
Fixed carbon	48.7	46.4	47.7	40.9	32.9	28.2	30.2
Ash	8.0	4.6	12.3	3.0	5.8	8.4	5.8
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
B.t.u. per pound	13,320	13,100	11,540	10,200	7,790	7,260	6,800
Yields, percent							
Char	69.7	65.0	72.0	58.2	48.0	45.7	45.0
Tar + L. O.	17.8	19.6	10.0	10.4	6.7	7.3	4.0
Gas	5.8	5.8	5.0	5.4	7.4	7.0	8.2
Water	6.7	9.6	13.0	26.0	37.9	40.0	42.8
	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Tar + L. O. gal/ton	41.0	44.0	24.3	24.0	15.4	17.0	9.3
Potential heat distribution, percent							
Char	69.5	68.0	77.0	76.0	77.0	76.0	80.7
Tar + L. O.	22.0	23.0	14.3	17.3	14.6	17.0	10.7
Gas	7.0	7.0	7.2	6.3	6.0	5.0	6.6
	98.5	98.0	98.5	99.6	98.0	98.0	98.0
Char B.t.u./lb.	13,270	13,700	12,350	13,300	12,500	11,430	12,100
Net heat char/coal	0.71	0.73	0.79	0.79	0.82	0.77	0.87

1/ Moisture-and ash-free

Coal and Lignite for Industrial Uses*

than the value of the raw coal on a heat basis because a power plant can burn almost any grade of fuel efficiently. Char may have superior value because of its improved physical and chemical properties and this must be considered in assigning a value to the processed fuel. For example, a lignite of 7,000 Btu/lb heating value containing 36 per cent moisture definitely has less value for fuel, on a heat basis, than a dry char of 11,000 Btu/lb which can be made from the lignite by carbonization. The char can be burned at higher efficiency, higher temperature, and with higher heat release per cubic foot of furnace volume and can be handled at lower cost.

If a power plant is obliged to use lignite for fuel, the cost of suitable facilities to partly dry and pulverize the lignite for efficient combustion is substantial, and the combustion chamber of a conventional steam-generating unit has to be modified to burn the high-moisture lignite efficiently. The cost of drying and carbonizing facilities for producing a high-grade fuel of about 11,000 Btu/lb for combustion in a slagging type furnace may not be much greater than the cost of lignite pulverizing and drying equipment required for conventional pulverized fuel firing in a non-slagging type furnace; consequently, the net cost for processing may be quite low. The net cost is the difference between the two methods of utilization in terms of fuel cost at the burner after the value of the tar is credited, as shown in Fig. 2, next page.

If coal is to be carbonized successfully for power-plant fuel the value of the tar must more than pay for the net cost of processing. To accomplish this, the net cost of processing must be low and the time required for carbonization as short as possible. This is a difficult technical and economic problem, and it is indicated from data presented in this paper that the power plant utilizing char as fuel must be at the mine, except when the yield of tar from the coal is very high, Fig. 2.

Large plants for drying and for experimental work on carbonizing lignite, using the processes developed by the Bureau of Mines at Denver, are now under construction by the Texas Power & Light Co. for the Aluminum Co. of America at Rockdale, Texas, where a 240,000-kw steam-electric power plant will use dried lignite and char to furnish electric power for the aluminum-smelting works. This new development has created considerable interest in coal distillation, and the Bureau of Mines has received many inquiries as to the possibilities of using low-temperature carbonization of various coals to provide fuel for electric power plants.

Coal Properties and Yields

Generally speaking, all coals having an ASTM classification up to and including high-volatile C bituminous can

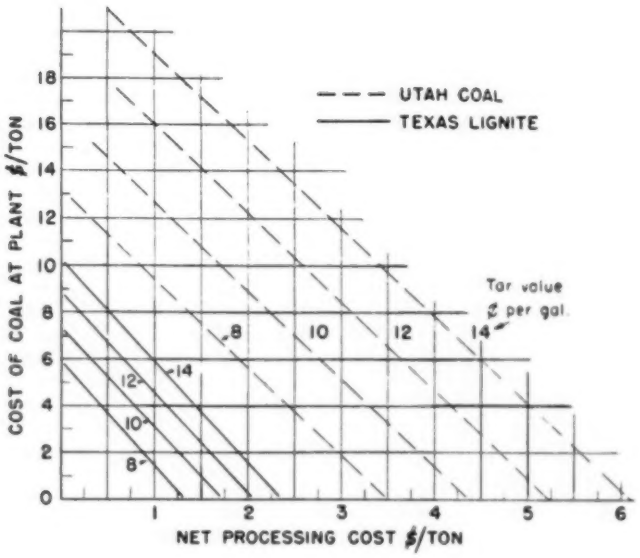

Fig. 2—If the value of tar reaches 14 cents a gallon and Texas lignite costs only $1 a ton at the plant, process costs can go $2.20 per ton.

Table 2. Properties from fluidized carbonization at Sandow

Condition	Raw lignite	Dried lignite	Char
Yield, weight percent	100.0	69.6	49.7
Proximate analysis, as received, percent			
Moisture	33.5	4.7	
Volatile matter	28.5	39.1	24.3
Fixed carbon	26.5	38.9	52.9
Ash	11.4	17.3	22.8
Ultimate analysis, as received, percent			
Hydrogen	6.6	4.8	3.0
Carbon	39.4	55.8	60.6
Nitrogen	0.8	1.0	1.4
Oxygen	40.6	19.4	10.6
Sulfur	1.2	1.7	1.6
Ash	11.4	17.3	22.8
Heating value, B.t.u./lb. gross	6,800	9,790	10,140
Heating value, B.t.u./lb. net	6,230	9,440	9,850
Size consist, cum. percent			
retained on No. 8	28.9	5.1	
16	53.6	23.6	1.6
50	82.8	72.6	45.2
100	89.5	83.6	65.2
200	95.0	91.6	82.1
Average size, inches	0.067	0.035	0.014

be considered suitable fuels for rapid carbonization at low temperature in a fluidized or entrained state. When such coals are carbonized, the heating value of the pure char is approximately 14,000 Btu/lb from any of the fuels considered, because all of the water and much of the oxygen have been evolved during carbonization. Despite the great variation in physical and chemical properties of the different lower rank coals in their raw state, the pure chars produced therefrom are substantially of the same basic quality. They are characterized by their high reactivity and ease of ignition.

The yield of primary products of distillation from different coals varies widely. Table 1 shows the analysis of and products from seven typical United States coals varying in rank from lignite to high-volatile bituminous A. The table shows that the yield of tar and light oil will vary from 9.3 to 44 gal/ton, depending upon the rank of the coal. In the lignites, 76 to 80 per cent of the heat remains in the char, or about 45 per cent of the weight of the raw coal, but in the higher rank coals the char represents about 70 per cent of the heat and about 70 per cent of the yield on a weight basis. Carbonization upgrades the lignites considerably by driving off inert gases and water, so the heating value of the char is just slightly lower than the heating value of chars from the higher rank coals. The ratio of net heat in the char to net heat in the coal increases as the rank decreases.

Heat to Carbonize

For practical purposes and for engineering design, the heat required for carbonization can be considered equal to the sensible and latent heat in the products of carbonization at the temperature they leave the retort. No credit should be taken for any exothermic heat of reaction. The following example illustrates the calculation of the heat of carbonization for a Texas lignite and a Utah bituminous coal when carbonized in a fluid bed at 900 F. The calculations in column on right are based on product yields shown in Table 1.

		Heat Required Btu/lb of Raw Coal
Texas lignite		
Char	$= 0.457\ (900-60)\ 0.28$	$= 107$
Tar	$= 0.073\ (900-60)\ 0.75 + 0.073 \times 135$	$= 56$
Gas	$= 0.07\ (900-60)\ 0.39$*	$= 23$
Water	$= 0.40\ (900-60)\ 0.47 + 0.40 \times 1060$	$= 582$
Total		768
Utah bituminous		
Char	$= 0.65\ (900-60)\ 0.28$	$= 153$
Tar	$= 0.196\ (900-60)\ 0.75 + 0.196 \times 135$	$= 149$
Gas	$= 0.058\ (900-60)\ 0.59$	$= 29$
Water	$= 0.096\ (900-60)\ 0.47 + 0.096 \times 1060$	$= 140$
Total		471

* The specific heat of gas from lignite is different from that of gas from bituminous coal because of different constituents.

The above calculation shows that the heat required to dry and carbonize lignite is about 65 per cent more than the heat required to carbonize bituminous coal because of the large amount of water that must be expelled from lignite. The heat required for this duty amounts to over 75 per cent of the heat required for carbonization. Therefore, when lignite is processed, a drying and preheating operation should precede the carbonization step. When processing a bituminous coal, the two-step operation may not be necessary, and all of the heat for carbonization might be supplied in one operation. If this can be accomplished with the high-volatile noncoking coals, such as those produced in Carbon County, Utah, and in western Wyoming, from which 30 to 44 gal of tar per ton can be extracted, the fuels could be processed profit-

Table 3—Heat and material balance on 8-in. reactor

	°F	SCFH 3/	Pounds	Sensible-heat balance		Potential heat balance	
				B.t.u.	%	M gross B.t.u.	%
INPUT							
Dried coal	176		360.5	7,530	4.4	3,529.3	100.0
Air	103	1,059	81.1	830	.5		
Heat of combustion 1/				105,900	61.7		
Heat transferred 2/				57,280	33.4		
		1,059	441.6	171,540	100.0	3,529.3	100.0
OUTPUT							
Char	900		257.4	61,780	36.0	2,551.6	72.3
Tar and light oil	900	72	33.1	22,710	13.2	562.0	15.9
Process gas	900	1,334	107.1	26,425	15.4	230.1	6.5
Liquor	900	876	41.7	60,630	35.4		
Heat of combustion						105.9	3.0
Unaccounted			2.3			79.7	2.3
		2,282	441.6	171,540	100.0	3,529.3	100.0

1/ Assuming 100 gross B.t.u./SCF of air used.

2/ Obtained by difference; heat obtained from the external combustion of 222 SCFH 3/ natural gas, 980 B.t.u./SCF.

3/ Standard cu. ft./hr. at 60°F. and 30 in. Hg abs.

Table 4—Overall sensible heat and material balance

	Temp. °F	MSCFH 3/	Pounds per hr.	Million B.t.u. per hr. net
INPUT				
Raw lignite, 34.6% moisture 1/ 10.1% ash	75		79,660	0.30
Air	100	469	35,790	0.34
Net heat liberated 2/				33.56
		469	115,450	34.20
OUTPUT				
Ash retained in furnace	1500		70	0.02
Dried lignite product, net 5.4% moisture 14.7% ash	247		51,760	2.42
Dust lost out of stack	250		400	0.02
Products of combustion	250	489	38,640	1.82
H_2O evaporated from lignite	250	517	24,580	28.17
Heat loss (radiation)				1.75
		1,006	115,450	34.20

1/ Proximate analysis of raw lignite (MAF): B.t.u./lb 12,900; VM 49.1; FC 50.9; 100.0

2/ From combustion of 3950 pounds of dried dust from cyclone separators analyzing 68.0% MAF material, 27.8% ash, and 4.2% moisture. Heating value 8,800 B.t.u./lb gross, 8,500 net.

3/ Thousand standard cubic feet per hour 60°F. 30 in. Hg abs.

ably some distance from the mine. Several basic methods can be applied in carbonizing coals or lignite. In an early Bureau of Mines pilot unit, Fig. 1, dried coal is moved with air into the base of an externally heated vertical reactor. Heat is transferred from the wall of the reactor to the suspended mixture, and the air reacts with the coal to supply a substantial portion of the heat required for carbonization. All products of reaction, including char, tar vapors and gas, leave the top of the reactor and the separation of the products is made in suitable equipment.

The one selected for processing lignite at Rockdale, Texas, and developed by the Bureau of Mines at Denver, in cooperation with Texas Power & Light Co., follows this general scheme:

The gaseous products inside the reactor move upward at a superficial velocity of 6 to 8 fps near the top of the reactor. Some 30 to 40 per cent of the heat required for carbonization is transferred through the wall of the reactor and 60 to 70 per cent is derived from combustion of air and carbon inside the retort. Approximately 80 Btu is transferred to the coal from each cubic foot of air introduced with the coal; consequently, 2 to 4 cubic feet of air is required for each pound of dry lignite carbonized. Reactions can be controlled automatically by regulating the heat transferred through the wall and by changing the air-coal ratio. This method has certain advantages: the capacity and efficiency are high, and the product gases' heating value increases from the external heat.

Compared to other systems of carbonization, fine coal is heated in a minimum time, and the capacity of a reactor is relatively very high. About 12 minutes is required to carbonize the coal and the capacity of the reactor is 60 to 90 lb per cu ft of reactor volume per hr, depending upon diameter and volume of the reactor. The ratio of heating surface to reactor volume has to be properly balanced to permit up to 40 per cent of the required heat to flow through the wall of the reactor.

By suspending fine coal in a gas stream moving upward, the fine coal particles, which take only a short time to carbonize, sweep through the reactor rapidly, and the larger particles move through the system at a rate inversely proportional to their size. Thus carbonization of all sizes is attained in the minimum time, depending upon the superficial velocity of the gases. The reactor is suspended in a furnace and is heated by combustion of process gas, which is burned in direct contact with the retort, producing rapid transfer of heat to the reactor by direct radiation from the gas.

Development Work

At Rockdale, lignite will be extracted within a few miles of the plant and conveyed to it on a continuous belt. The 6-in. × 0-in. size lignite received at the plant will be crushed to about minus $^1/_4$-in. size in hammer mills and placed in temporary storage in nine concrete silos. From these silos the raw lignite is handled in closed circuits and conveyed through the drying operations by pneumatic transport. When dried lignite is used as fuel two driers will be capable of supplying the fuel requirements for each 80,000-kw unit. If and when char is used as power-plant fuel the dried lignite will be moved through the carbonizers pneumatically. Three driers and three carbonizers will be required to supply the fuel for each 80,000-kw unit at maximum capability.

During 1952 a prototype drying unit, installed at Rockdale, Texas, operated several months to refine the engineering and processing details. Performance tests and automatic control of this unit were successful; but it was observed that, due to limitations caused by low softening temperature of the lignite ash, the nominal rating of this unit was 40 tons of raw lignite per hr. The 9 units installed in the final plant will have a nominal rating of 50 tons per hr each when lignite containing 36 per cent moisture is dried to a product containing about 4.0 per cent moisture.

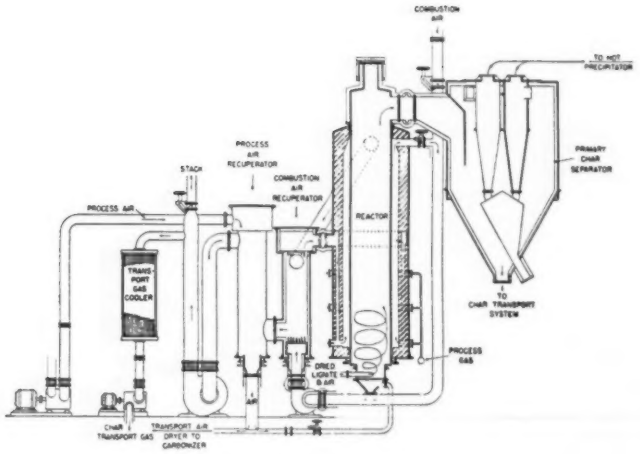

Fig. 3—Schematic layout of the lignite drying unit which will handle combustion products at 1500 F and 314 psig into the drier chamber.

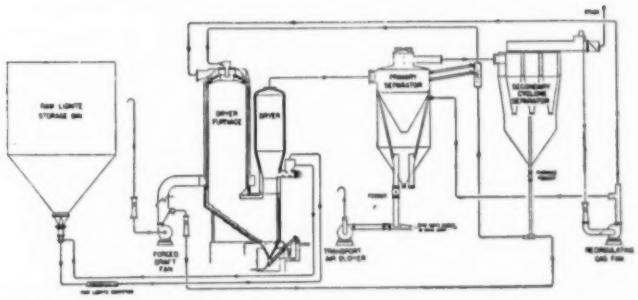

Fig. 4—Prototype carbonizing unit has reactor of alloy steel, 6 ft dia by 35 ft high, where the mixture of lignite and air carbonizes.

Crushed raw lignite moves from the storage silos by means of a closed loop conveyor which maintains an oversupply of lignite at the small hopper above the screw feed in the drier. Products of combustion at about 1500 F produced by combustion of dried lignite dust with air and recirculated gases enter the drier section at a pressure of about $^3/_4$ psig. The wet lignite is suspended in this drying column in a turbulent state. The fuel to the furnace is regulated automatically to produce a given temperature at the exit of the drying section. Normally this temperature is about 300 F when the stack temperature is 275 F. About 94 per cent of the dried dust settles out in the primary separator, and the balance of the dust is separated in a secondary cyclone. The final dust from the cyclones, then, returns to the furnace for combustion. And the dried dust from the primary separator is moved with air to the boiler-plant storage silo or to the carbonizer. Table 4 shows a heat and material balance on the prototype drier.

Carbonizing Equipment

A prototype carbonizing unit, Fig. 4, designed to handle 31 tons of dried lignite per hr has been built similar to the smaller unit previously operated by the Bureau of Mines at Denver[1] and is designed for automatic control. Its reactor is of alloy steel, 6 feet in diameter and 35 feet in height, mounted in a special furnace equipped with recuperators for efficient operation and preheating of process and combustion air. The process air, compressed to about 8 psig, passes through a recuperator where it is preheated to about 700 F. Part of this preheated air is diverted back to the drier to pick up the dried lignite for transport to the reactor, and another part of the air goes directly to the base of the reactor. The mixture of air and coal enters the base of the reactor, and the fine coal moves upward through the reactor to become entrained in the products of reaction in a turbulent condition. The solids are not in a true fluidized state because of the high superficial velocity of 6 to 8 fps. The temperature of the products leaving the top of the reactor is controlled automatically by regulation of the combustion around the reactor or by regulation of the air-coal ratio similar to methods employed in smaller pilot plants.

A fan draws the combustion air into the system and also circulates a portion of the products of combustion from the furnace. This mixture enters the fan at about 600 F and is forced through the combustion air recuperator, where it is preheated to about 1200 F. From this recuperator the mixture of air and products of combustion passes to the furnace ports through a series of flues connecting the distributing bustle with each port. The air-gas ratio is controlled to provide about 5 per cent excess air and the recirculated products of combustion are regulated to secure a maximum flame theoretical temperature in the reactor of about 2700 F. The developed temperature around the reactor, however, is controlled to less than 1900 F to protect the heat-resisting alloy.

Under these conditions of combustion the rate of heat transfer to the reactor wall is maximum because of the high heat transfer by direct radiation from the gases. Rates of heat transfer exceeding 11,000 Btu/hr/sq ft have been attained in the pilot model at Denver and it is expected that the rate will be in the range of 9,000 to 10,000 Btu/hr/sq ft in the large unit when operating at rated capacity. The volume and heating surface of the reactor have been selected to permit carbonization of the coal at a rate of about 60 lb/hr/cu ft when the superficial velocity is 6 to 8 fps.

The product char is collected in the primary and secondary separators at 900 F. This char is moved to the boiler plant without cooling by pneumatic transport, using products of combustion produced in the system. At the boiler plant the char is separated in cyclones and deposited in a 150-ton bin mounted on the boiler structure. From this bin the fuel is fed to the several tangential burners. The bin is protected by a suitable circuit of inert gases.

The prototype carbonizer, Fig. 4, a hot electrostatic precipitator, together with an experimental tar-condensing system, will be operated several months to prove the design and engineering features and to produce tar for research market studies. Experience from this operation will indicate the probable economics and optimum design for a complete carbonization plant. The value of the tar has not yet been established, as it is a comparatively new substance and has thus far never been available in large enough quantities to justify the necessary and expensive commercial research investigations. Extensive work must be done on chemical composition production methods, products obtainable, and uses and markets for the products before an accurate estimate can be made of the value of the tar.

[1] Parry, V. F., Landers, W. S., Wagner, E. O., Goodman, J. B., Lammers, G. C., "Drying and Carbonizing Fine Coal in Entrained and Fluidized State" R.I. 4954, Bureau of Mines, 1953.

Methods of Starting Gas Turbine Generator Sets*

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J. G. PARTLOW

Westinghouse Electric Corporation

Starting gas turbines involves a number of special problems which are discussed in this AIEE paper. Representative starting equipment is described and electrical considerations are explained.

WHEN combustion gas turbines are started, they are usually accelerated to approximately 20 to 25 per cent of rated speed before the combustor is fired. Further assistance during starting is usually required until the speed reaches 40 to 60 per cent of the rated value. The starting problem arises because of the need to assist the gas turbine through the lower speed range with a separate cranking device until operation of the turbine becomes self-sustaining. At higher speeds the turbine requires no further assistance to accelerate to the normal running speed.

In order to select a suitable starting device, we should first examine the requirements which will be imposed upon it by the nature of the gas-turbine unit, the location of the station, and the availability of supply.

General Arrangement

A gas turbine-generator unit normally consists of a rather conventional turbine generator, excited by a direct-connected exciter, and driven by either a direct-connected or geared gas turbine. The gas turbine portion of the unit consists of one or more turbines and air compressors, the combustor, and such associated heat exchanger apparatus as may be required. The physical arrangement of the major components of the gas turbine depends upon the type of cycle that is used. This arrangement of components is a primary factor in determining the starting requirements of the unit.

Three gas turbine arrangements are illustrated in the diagrams of Fig. 1. Diagram 1(a) shows the simple open cycle configuration. All rotating equipment is mechanically coupled together to run at constant speed.

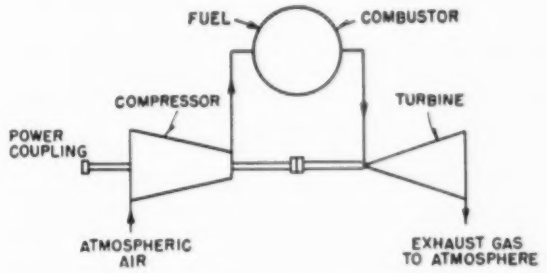

Fig. 1(a)—Simple open cycle, single shaft

Diagram 1(b) shows a two-shaft gas-turbine arrangement with regenerator. The regenerator is used to improve fuel economy at all loads, and the mechanically independent power turbine allows a reduction in the speed of the gas producer (or compressor) section at part load so as to obtain further improvement in fuel economy.

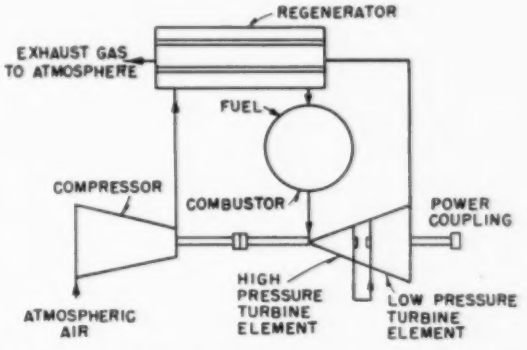

Fig. 1(b)—Open cycle with regenerator, series flow, two shaft

Diagram 1(c) illustrates a high efficiency cycle with compressor intercooling, regeneration, and a two-shaft arrangement. In this particular plant, the power coupling is on the shaft containing the high-pressure turbine and compressor.

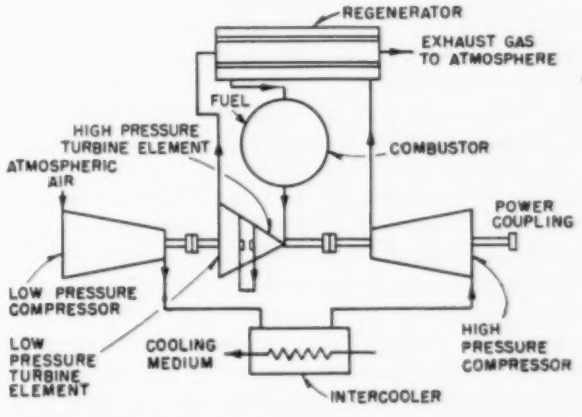

Fig. 1(c)—Open cycle with regenerator and intercooler, series flow, two shaft

* Paper presented before the Winter General Meeting of the American Institute of Electrical Engineers, New York, January 18–22, 1954. Slightly abridged.

The arrangements of Figs. 1(a), 1(b), and 1(c) are representative of machines built or in manufacture by the Westinghouse Electric Corporation, but various configurations are possible. Reduction gears are employed in the machines represented by Figs. 1(a) and 1(b) to permit the turbine speed to be in excess of the speed of the generator.

Location of the Starting Device

It is usually necessary to accelerate the gas-producer (or compressor) components of a gas turbine. In Fig. 1(a), the entire compressor and turbine assembly must be cranked. In Fig. 1(b), only the compressor and compressor drive turbine, which comprise the gas producer section, must be cranked. In Fig. 1(c), where two mechanically independent shafts are used and each shaft drives a compressor, it may be desirable to have a starting device on each shaft.

In the case of the simple open-cycle, single-shaft unit, shown in Fig. 1(a), the location at the outboard end of the turbine element is not advantageous for two reasons. One is that thermal expansion of the turbine parts complicates the problem of supporting the starting device. The other is that units of this type use a geared turbine having a speed so much higher than the generator speed that many starting devices are eliminated on the basis of speed alone, unless the starting device were to drive through an additional gear. This would require the use of a high-speed clutch or continuously operating gears.

In the case of the two-shaft, open-cycle unit shown in Fig. 1(b), the cranking device must be coupled to one end of the shaft which carries the compressor and its turbine element. When an integral casing is used for the turbine elements, the shaft ends within this casing are inaccessible. This leaves the outboard of the compressor as the only suitable location. Because of the high speed of this shaft, a gear is necessary if the electric motor is to be used as the starting device.

Similarly, for the low-pressure element of the high-efficiency cycle shown in Fig. 1(c), the starting device is located on the outboard end of the plant on the low-pressure compressor so as to avoid the high-temperature elements and ducts. For the high-pressure element of the same high-efficiency cycle, similar considerations indicate that the starting device be attached to the generator or exciter at the opposite end of the plant.

When a gear is used between the turbine and the generator, it is sometimes convenient to connect the starting device to the unit through additional gearing incorporated into the design of the main gear. Whether this location is attractive depends largely upon the arrangement of the adjacent major components of the unit and upon the method of coupling the starting device to the gear.

Another location considered for the cranking equipment is between the generator and direct-connected exciter for the simple open cycle of Fig. 1(a) and for the high-pressure element of the high-efficiency cycle of Fig. 1(c). The principal limitation of this location is that it is suitable only for a continuously rotating electric motor. An advantage in the use of this location for a starting motor is the fact that an exciter of conventional size may be used since the exciter shaft is not required to transmit the cranking torque or to withstand abnormally high transient torques.

The outboard end of the exciter has been selected as the location for the starting device for the simple open cycle of Fig. 1(a) and for the high-pressure element of the high-efficiency cycle of Fig. 1(c). The chief advantage of this position is that it provides considerable latitude in the selection of starting equipment. For this arrangement, a special exciter is provided which incorporates a shaft strong enough to transmit the cranking torque.

Methods of Connecting Starting Device

Two general methods may be used to connect the starting device to the gas turbine generator unit. Either a permanently-connected coupling may be used or some kind of disconnecting clutch. The clutch which has found application in shop testing of gas turbines and which is incorporated in the design of recent gas-turbine units is a pneumatically operated disconnecting clutch. It is suitable for the speeds where cranking assistance is supplied, but it is not commercially available for transmitting power at high speeds.

Starting Requirements

It is usually necessary to accelerate the gas producer (or compressor) components of a gas-turbine unit to approximately 20 to 25 per cent of rate of speed before firing in order to provide sufficient air for the cycle. After light-off of the combustors, it is necessary to assist the turbine to approximately 50 to 60 per cent of rated speed, at which point operation of the turbine becomes self-sustaining. This speed is set by the aerodynamic design of the components and by the allowable turbine inlet temperature.

Fig. 2 shows typical speed-torque requirements of a gas turbine unit due to the inherent friction and windage load during the cranking period. The break-away torque is usually supplied by a turning gear, so that this requirement does not influence the selection of cranking apparatus. After break-away, the starting device must supply

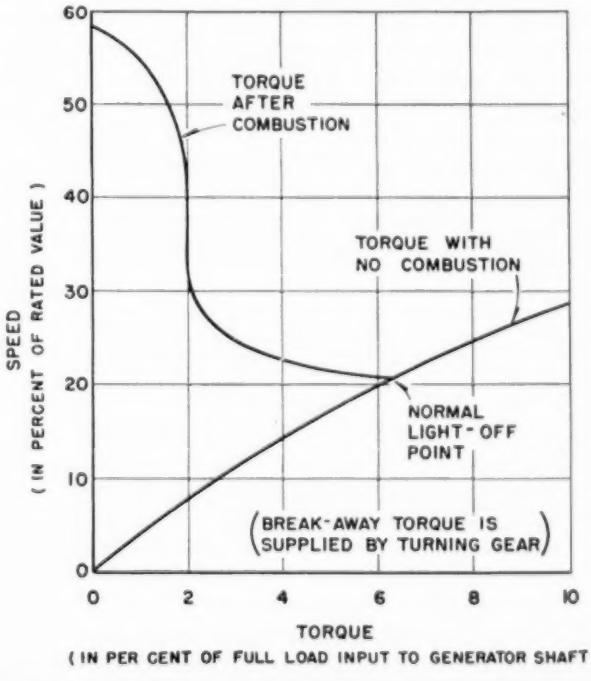

Fig. 2—Speed-torque requirements for starting simple open-cycle 5000-kw gas-turbine-generator unit

sufficient torque to overcome the friction and windage losses of the unit, and to accelerate its relatively high inertia to light-off speed within a reasonable length of time. As soon as combustion is obtained, the turbine supplies a portion of the necessary torque. However, a residual component of the friction and windage torque remains to be overcome by the cranking device as it continues to assist the turbine to reach a speed where turbine operation is self-sustaining.

When the turbine is operated at the lowest self-sustaining speed, the inlet temperature is higher than permissible for prolonged operation, and the compressor is in the region of surge. Therefore, the gas turbine unit is accelerated under its own power to a higher speed for idling and for operation under load.

From the considerations described, it can be observed that the torque required for the starting equipment is primarily influenced by the friction and windage torque of the unit at the ignition speed. A second consideration is seen to be the allowable time to accelerate the inertia of the unit to self-sustaining conditions. Generally speaking, the starting time of a gas turbine unit will be of the order of 3 to 6 minutes.

Naturally, it is desirable to have a starting device place no limitations on the operation of the unit. A starting duty cycle should be selected that does not unduly restrict the operation of the turbine-generator unit, but at the same time does allow a selection of cranking equipment of moderate size or rating, making use of any overload capabilities inherent in the cranking device for time intervals comparable to the cracking period.

It is felt that the starting device should be capable of two different duty cycles. One of these duty cycles consists of accelerating the unit twice from turning gear speed to light-off speed and then accelerating the unit once from light-off speed to self-sustaining speed. A suitable cooling period is allowed to permit the starting device to cool, if necessary, before this cycle is repeated or before the other duty cycle is started.

In addition to its starting duty, it has been found desirable to use the starting device to spin the unit at the speed equal to or less than the light-off speed, sometimes for prolonged periods. This permits rapid cooling of the turbine parts during the initial portion of a shutdown period. It also permits inspection and adjustment prior to putting the unit on the line during the initial stages of operation or following a prolonged shutdown.

Therefore, the other duty cycle consists of accelerating the unit to the spinning speed, maintaining that speed for 15 to 30 minutes, and accelerating the unit from the spinning speed to self-sustaining speed. Here again, a suitable cooling period is allowed.

Occasional Operation as a Synchronous Condenser

In some applications it may be desirable to use the generator as a synchronous condenser during part of the year. This can be done by using a special coupling between the gas turbine and the generator which allows the generator to be uncoupled from the turbine and to run by itself as a synchronous condenser. This type of operation requires some means of accelerating the generator to a speed slightly above its synchronous speed. When operation of the generator as a synchronous condenser is desired, this requirement should be considered in selecting a starting device for the unit.

Types of Starting Devices

The actual starting devices themselves include internal combustion engines, expansion turbines, and electric motors of various types, both a-c and d-c.

An expansion gas turbine is particularly applicable where a source of high pressure gas exists near the unit, as might be the case near gas fields or gas pipe lines. However, it is limited to those areas where the discharge of unburned gas into the atmosphere during the starting period is not objectionable. It must be coupled to the combustion gas turbine-generator unit through a disconnecting clutch.

Although an internal combustion engine may be used as a starting device regardless of the location of the power plant, its application is usually considered to be limited to remote locations where adequate electric power is not available. It must be coupled to the turbine-generator unit through a disconnecting clutch.

A permanently-coupled induction motor suitable for continuous idling at 3600 rpm offers several advantages. Because a wound-rotor induction motor cannot be used for such a high-speed application, the induction motor to be considered must be either a squirrel-cage motor or a solid-rotor, eddy-current motor. The controls for either of these are much simpler than for a wound-rotor induction motor. The absence of a disconnecting clutch, when this type of motor is used, simplifies the mechanical arrangement and eliminates a device which might require maintenance. The windage loss of the rotor of the motor, even at 3600 rpm, is not sufficient to be objectionable. A disadvantage of this arrangement is the relatively high inrush current of the types of induction motor which can be used.

Although placing a motor between the generator and the exciter is workable, it is not a preferred arrangement. It prevents the designing of generator-and-exciter combinations as standard packages and renders the unit less adaptable to changes in the type of starting device which could be used for subsequent orders, shop testing, or emergency operation.

Negative Damping

If either a squirrel-cage induction motor or a solid-rotor induction motor were solidly connected to the outboard end of the exciter, a phenomenon of negative damping could develop due to the flexibility even of an oversized exciter shaft. This results from the fact that during part of the acceleration period, the motor would be operating at a speed below the pull-out point of the speed-torque curve. In this speed range, any increase in speed is accompanied by a further increase in torque, and any decrease in speed is accompanied by a further decrease in torque. Torque pulsations, if once initiated, could develop into large torque surges which, in extreme cases, could cause mechanical failure. In the usual application of a squirrel-cage induction motor to a conventional type of load, the motor accelerates the load through this critical speed range at a sufficiently rapid rate to avoid excessive torque surges due to negative damping. However, when a squirrel-cage motor starts a gas turbine, there is the possibility that the acceleration period might be long enough for excessive torque surges to develop. Therefore, it has been considered the best conservative practice to avoid negative damping entirely by not solidly

coupling a squirrel-cage motor or solid-rotor eddy-current motor to the outboard end of the direct-connected exciter. This situation permits us to consider the squirrel-cage and solid-rotor induction motors only when coupled through a disconnecting clutch which inherently possesses sufficient positive damping to eliminate the negative damping problem.

Thus, the solid-rotor induction motor is preferable to the squirrel-cage induction motor; and for maximum adaptability, a design with the starting device on the outboard end of the exciter is preferred. In this location, such a motor, coupled through a clutch, will avoid excessive torque surges resulting from negative damping.

A desirable starting device to be considered now is the wound-rotor induction motor. Because it is not suitable for speeds as high as 3600 rpm, it must be disconnected by the use of a clutch when its own speed is near 1800 rpm. At this speed a 4-pole, 60-cycle motor has ceased to contribute to the acceleration of the turbine. As in the case of the other types of induction motors, a gear must be used to permit the motor to accelerate the turbine to a high enough speed for turbine operation to be self-sustaining. This type of motor is satisfactory for gas turbine cranking because of its relatively low inrush current and because its operation can be regulated so as to operate in the range between synchronous speed and pull-out speed where there is no problem from pulsating torques due to negative damping.

Use of a Clutch

A further advantage results from the use of a clutch with an electric starting motor. In case the motor is heated by prolonged use or repeated cranking operation, the starting motor can be disengaged from the gas turbine unit and run at no load for a long enough period to dissipate the heat stored in the motor. This eliminates the need for a separate motor-driven blower to cool a starting motor when at rest, and it tends to reduce the cooling period that the motor would require before repeating its duty cycle.

Basically the gas turbine starting problem involves the acceleration of a very high inertia load. A d-c motor is particularly suited to this type of duty since it does not have the slip losses at low speeds that impose such a heavy thermal duty upon induction motors during the starting cycle. When the exciter must serve also as a d-c starting motor, it may be 5 times as large as its excitation duty would require if the arrangement shown in Fig. 1(a) is used. For the arrangement shown in Fig. 1(c), the exciter might be 2 to 3 times the normal size. Because of the wide range of currents which such a d-c machine must carry, it is considered necessary to reduce the number of carbon brushes in service after the machine changes from starting motor operation to exciter operation. Otherwise the large number of brushes used for carrying the heavy current during the starting period would be operated at much too low a current density during normal exciter operation. Brush chatter and poor commutation would result. Thus, some method of brush lifting is necessary if the exciter is used for starting. A motor-generator set must supply variable voltage d-c during the starting cycle, and a rather complicated control scheme is required. It should be noted, however, that the kva demand of the motor driving the d-c generator is substantially less than the kva demand

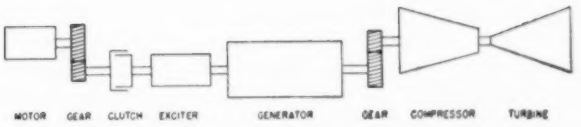

Fig. 3—Schematic diagram of a typical 5000-kw gas-turbine generator unit

of any of the induction-motor starting devices. Another advantage of the use of the exciter for starting is the possibility of using the same exciter for accelerating the generator to a speed slightly above 3600 rpm after it has been uncoupled from the turbine for operation as a synchronous condenser.

Representative Gas Turbine Starting Equipment

The Westinghouse 5000-kw simple gas turbine unit has been selected to demonstrate a specific example of cranking apparatus. Fig. 3 shows a schematic diagram of this unit, with a starting motor arranged as dictated by the previously described considerations. This unit requires assistance up to a speed greater than the 4-pole synchronous speed of 1800 rpm in order not to exceed allowable turbine inlet temperatures; so gearing is employed for the starting motor.

The friction and windage speed-torque relationship, shown by Fig. 2, was considered previously. Torque at light-off speed was indicated as approximately 6 per cent of the generator rating. A representative starting motor torque is, therefore, about 10 per cent of the generator rating in order to produce satisfactory acceleration. This does not mean that the starting device must have a rating equal to 10 per cent of the turbine rating, because it is necessary for the starting device to assist in the acceleration of the turbine only up to approximately 60 per cent speed and also because the maximum load torque requirements occur at approximately 20 per cent of rated speed.

If it is assumed that 10 per cent torque is required at speeds up to 60 per cent of rated speed, the starting device must then have a rating of approximately 6 per cent of the turbine rating. However, this does not take into account the fact that this device is to be used only during the starting period. By taking advantage of the overload capabilities of the device, the size can be considerably reduced.

The inertia of this unit is quite high, since the gas turbine has an inertia approximately five times that of the generator when referred to the generator shaft. Thus, the ratio of the stored energy of the rotating parts of the unit at rated speed to the generator kva rating is approximately 14.

Fig. 4 shows an overhead view of a 5000-kw gas turbine-generator unit during assembly on the test floor. On the extreme right is the generator with side-mounted air coolers. Next is the 5700/3600-rpm single-reduction gear. Connected to the reduction gear is the 16-stage axial air compressor which takes in approximately 97,000 cfm of air and compresses it from atmospheric pressure to 85 psia. This compressed air enters the combustion chambers. There are six annular combustors arranged between the compressor discharge and turbine inlet. Fuel is admitted and burned to heat the compressed air to approximately 1350 F. This heated air expands

through the five-stage gas turbine, shown at the extreme left on Fig. 4. The gas turbine converts the heat energy into mechanical energy to drive the axial air compressor and 5000-kw generator. The gas exhausts from the turbine at atmospheric pressure and 750 F.

Fig. 5 shows an installation photograph of a 5000-kw, simple open-cycle, gas-turbine power plant for electric power generation. This is a base load plant and utilizes natural gas as fuel.

Electrical Requirements for Supplying Starting Motor

The required auxiliary electrical supply system is determined by the choice of starting method. Basically, there are three types of starting devices from the electrical standpoint. There are the wound-rotor induction motor, the solid-rotor eddy-current motor, and the d-c motor.

When using one of the induction motor starting schemes, it is very desirable to maintain the voltage at the terminals of the motor close to its rated value. If the voltage is allowed to drop below the rated value, the starting time will be increased; and if the voltage drop is severe enough, the starting motor may not be able to accelerate the turbine through the starting cycle or even to the light-off speed. If the starting time is increased due to undervoltage, there is also the possibility of exceeding the thermal capability of the starting motor. This undervoltage also would necessitate the lowering of the light-off speed. This could adversely affect ignition of the gas turbine and prolong the starting cycle still further. These considerations lead to the conclusion that it is very desirable to have an auxiliary power supply capable of maintaining rated voltage at the terminals of the starting motor.

Supply Systems

Two types of supply systems are encountered in studying the starting requirements for induction motor starting. The first type of system is characterized by a relatively stiff source supplying the auxiliary bus through a transformer. This might be a transformer connected to the terminals of an adjacent generator or a transformer connected to a high-voltage system. In general, the thermal requirements occasioned by the starting duty cycle determine the transformer rating for this type of supply. In sizing the transformer, consideration must be given not only to the starting motor load, but to any auxiliary load for the generator being started as well as any auxiliary load for other generators in the plant. This can be substantial if a gas compressor is used in preparing the fuel for the unit. On a 5000-kw unit the associated gas compressor requires approximately 150 horsepower. The transformer is usually connected to supply the starting motor with a no-load voltage that is approximately 10 per cent above the rated voltage of the motor. In general, a transformer suitable from the standpoint of thermal capability will have a voltage drop that will not exceed this 10 per cent margin.

The second type of supply system involves a small generator connected directly to the auxiliary bus. Due to the high synchronous reactance inherent in this auxiliary generator, it is essential that this generator be equipped with a voltage regulator. If this generator is operated with fixed excitation, either the voltage drops too low during the starting cycle, or it is necessary to apply an excessively high voltage to the starting motor before and after the starting cycle. In general, the voltage requirements will dictate the size of the exciter for the auxiliary generator and to some extent will dictate the size of this generator itself.

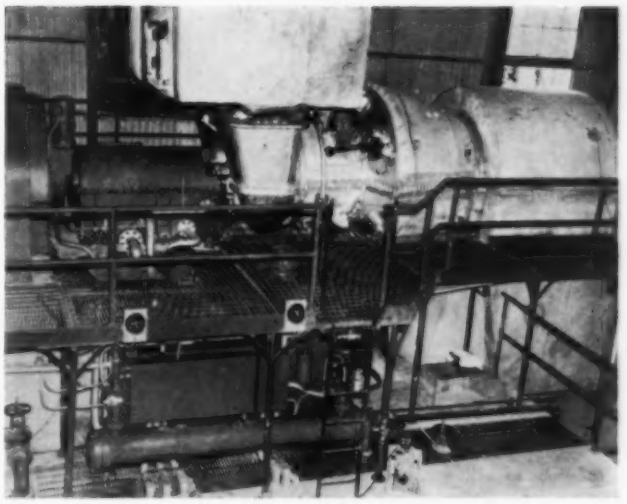

Fig. 5—Installation view of a 5000-kw simple open-cycle gas-turbine power plant

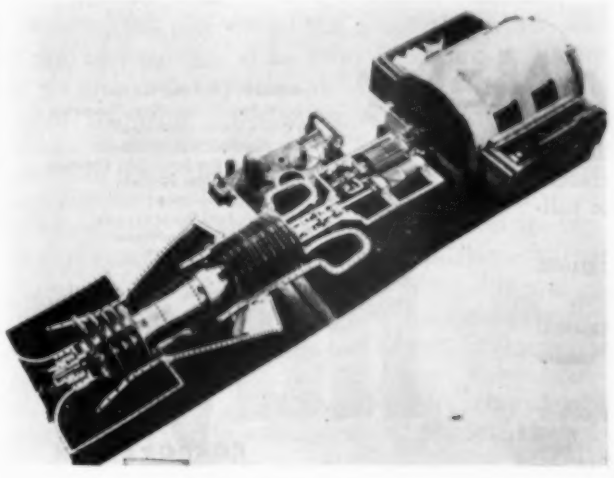

Fig. 4—5000-kw gas-turbine-generator unit

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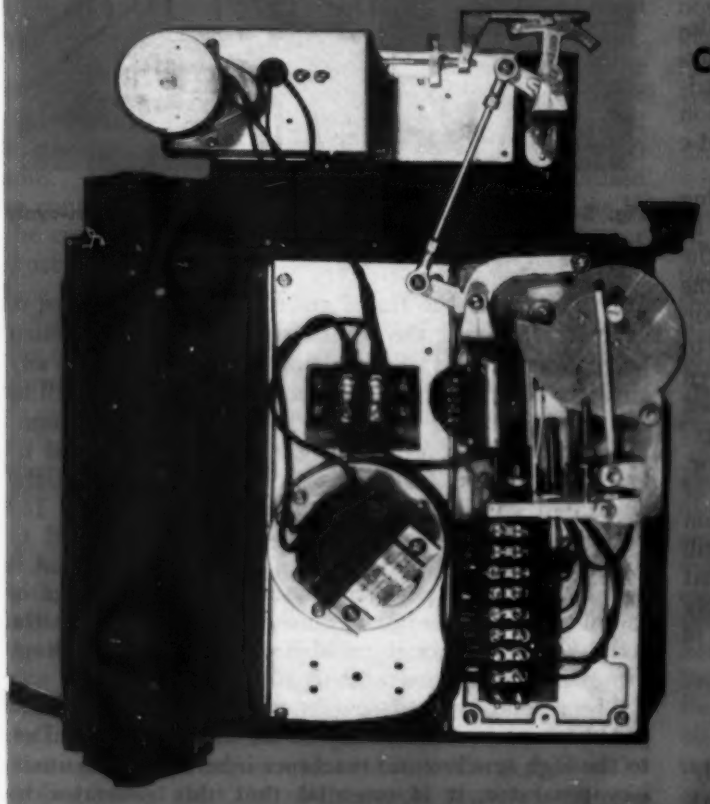

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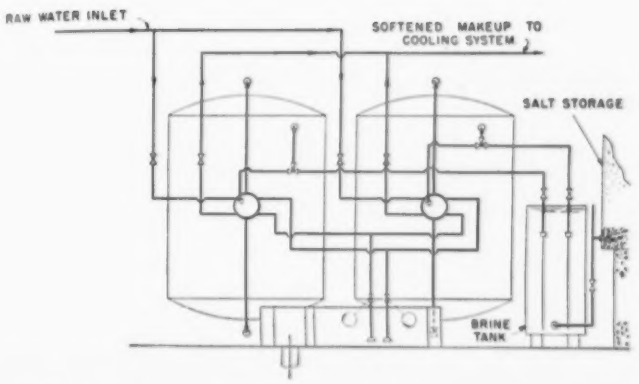


Fig. 1—Straight sodium zeolite softening of makeup water gives high heat transfer efficiency and reduced blowoff.

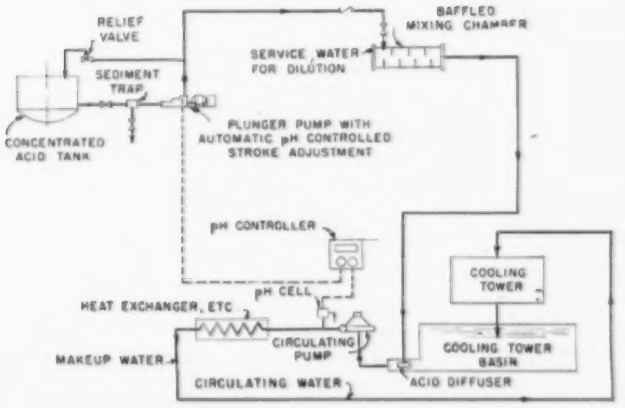


Fig. 2—Supplementary acid treatment often has to follow up zeolite method, Fig. 1, to reduce alkalinity and pH.

Cooling Water Treatment

By JAMES I. MUNSON
The Permutit Company

Until very recent years circulating cooling water systems and their problems have been in the province of large process industries almost exclusively. But water shortages, new load concentrations and fewer available natural sites have combined to bring the cooling tower into the power plant picture more frequently. Here's how their water treatment is handled.

BECAUSE of shortages of water, many power plants have installed and are in the process of installing circulating cooling systems which require relatively small amounts of water compared with the "once through" systems which are normally used where an ample supply of water is available. Makeup water is added to replace water lost by evaporation, windage and blowoff.

It is a simple matter to calculate losses from evaporation and windage in modern cooling systems using cooling towers. Evaporation of one pound of water in a cooling tower will absorb approximately 1,000 Btu's. Therefore, the evaporation of this one pound of water in the cooling tower will cool 100 pounds of water through a ten degree cooling range. Or, for each ten degrees of cooling in the cooling tower, approximately one per cent of the circulating water will evaporate.

In most forced draft cooling towers, approximately 0.1 per cent to 0.2 per cent of the circulating water is lost because of windage. This windage removal represents water lost completely from the system, and serves as a blowoff removing both water and solids. But solid buildup is considerable since this natural blowoff is slight. In fact the solids contained in the makeup water concentrate in the cooling system because most of the water loss is by evaporation. As a result the allowable concentration of solids in the circulating water determines the amount of blowoff required. If you wish to maintain a definite concentration of solids in the circulating water, the total solids introduced in the makeup water must equal the total solids removed by windage and by blowoff. A safe allowable concentration in the cooling system can be calculated and predicted based on the analysis of the makeup water and the operating conditions of the cooling system. Such an analysis will establish a concentration that gives little or no scale-formation in the cooling system and little or no corrosion.

From the calculated total allowable concentration, the number of concentrations of the solids in the makeup water can be determined. Then it becomes easy to calculate the blowoff requirements using the equation: Evaporation − Windage − Blowoff (B.O.) = No. of Concentrations (Windage − Blowoff).

This equation is derived as follows:

1. Total solids in = Total solids out.
2. Total solids in = Total solids in (Makeup)
   = Total solids in (Evap. − wind. − B.O.)
3. Total solids out = Total solids conc. (loss of water)
   = Total solids conc. (Wind. − B.O.)
4. Total solids conc. = Total solids in × No. of Concentrations
5. Total solids out = Total solids in × No. of Concentrations (Wind. − B.O.)
6. Total solids in (Evap. − Wind. − B.O.) = Total solids in × No. of Conc. (Wind. − B.O.)
7. Evap. − wind. − B.O. = No. of Conc. (Wind. − B.O.)

Having previously calculated the evaporation and the windage in gallons per minute and the number of concentrations, the blowdown in gallons per minute can then be determined.

Water Treatment Problems

Problems to be considered in the treatment of water to be used for cooling purposes may be classified in two categories: namely, chemical and physical.

Chemical: (1) Preventing excessive precipitation in the cooling system and subsequent scaling of heat exchanger surfaces. Excessive scaling will reduce the efficiency of heat transfer.

(2) Preventing oxidation or corrosion in the cooling system. Corrosion will destroy equipment and will also reduce heat transfer efficiency.

Physical: (1) Keeping mud, silt, etc., out of the cooling system to prevent plugging of heat exchangers, piping and valves.

(2) Preventing excessive sliming caused by algae and other organic growths which would cause plugging in the cooling equipment, and reduction of heat transfer efficiency.

Scale

The "Langelier Index" named for Prof. W. F. Langelier, is an indication of the tendency of a water to form calcium carbonate scale. It must be used as a guide rather than as a quantitative indication of the amount of scale which will be formed. However, it does indicate whether or not a water is likely to give trouble because of calcium carbonate. It cannot be used to determine the tendency of a water to form calcium sulfate scale. This is a different problem. Factors affecting the "Langelier Index" of a water are as follows: (1) temperature of the water; (2) total dissolved solids; (3) calcium hardness; (4) methyl orange alkalinity; (5) pH.

Each of the above with the exception of the "dissolved solids" tends to increase the scale-forming tendency of the water as its value gets greater. Increasing the dissolved solids in the water has a slight tendency to reduce the amount of scale-formation. The "Langelier Index" itself is the difference between a computed pH written as pH_s (called the pH of saturation) and the actual pH of the water. Actually, the "Langelier Index" of the water is the logarithm of its degree of calcium carbonate saturation. pH_s, as computed by the Langelier formula, is the pH at which the calcium carbonate present in a given water would be saturated if there were no change in the composition of the water. If the actual pH is higher than the pH_s, scale formation is indicated. If the actual pH is lower than the pH_s, corrosion is indicated. The pH_s is determined from the factors of temperature, total dissolved solids, calcium hardness and the methyl orange alkalinity listed above. This is then compared to the actual pH of the water. The determination of the pH_s is mathematical.

Normally, water treatment planning aims at a water whose "Langelier Index" is limited to a range of +0.5 to +1.0, that is, the actual pH of the water is not allowed to go more than 0.5 to 1.0 higher than the pH_s of the water. This gives a slight tendency toward scale-formation, but does not allow much deposition. It also protects against corrosion. This would be considered normal practice in water treatment for cooling systems.

Scaling in a cooling system is a serious problem. Usually, calcium carbonate and calcium sulfate are the two chemical compounds most likely to form scale. The most common approach to their control is the elimination or reduction of calcium carbonate so as to prevent scaling. However, after this has been fully considered a further study must follow to determine whether or not calcium sulfate may deposit out under the treatment conditions used for preventing calcium carbonate scale. If calcium sulfate scaling is indicated, the treatment may have to be varied or the number of allowable concentrations reduced.

Fig. 3—Delignification occurs with certain waters to produce long, stringy fibers and a weakened structure.

Where non-ferrous corrosion resistant alloys serve in the tubes of the heat exchanger equipment, straight sodium zeolite softening, Fig. 1, of the makeup water probably provides one of the best types of treated water makeup. It gives a high heat transfer efficiency and a reduced blowoff because the number of concentrations can be safely increased without scale-formation in the system. In some cases, windage alone provides sufficient blowoff and where this happens the maximum number of concentrations possible are obtained in the cooling system.

Supplementary treatment with acid, Fig. 2, often has to be done. The acid reduces the alkalinity and the pH of the circulating water to a point where the small amount of residual hardness present does not induce scaling nor does delignification occur in the cooling tower wood. Delignification is defined as the decomposition or apparent rotting of lumber caused by the reaction of sodium carbonate in the cooling water with lignins, tannins and the cellulose products of the wood. Delignification leaves the wood in long, stringy fibres, Figs. 3, 4, and reduces the structural strength of the wood.

Water Treatment

It will be noted from the above that the tendencies of a scale-forming water may be lessened by reducing: (1) the temperature of the process in which the water is being used; (2) the calcium hardness; (3) the methyl orange alkalinity; (4) the pH of the water. Because it is impossible to change the temperature materially in a cooling system, it becomes necessary to treat the water for reduction of calcium hardness, alkalinity, and pH. Normally, where the alkalinity equals or exceeds the calcium hardness, lime treatment, Fig. 5, produces maximum reduction of calcium alkalinity, and then a further acid treatment lowers the alkalinity and pH.

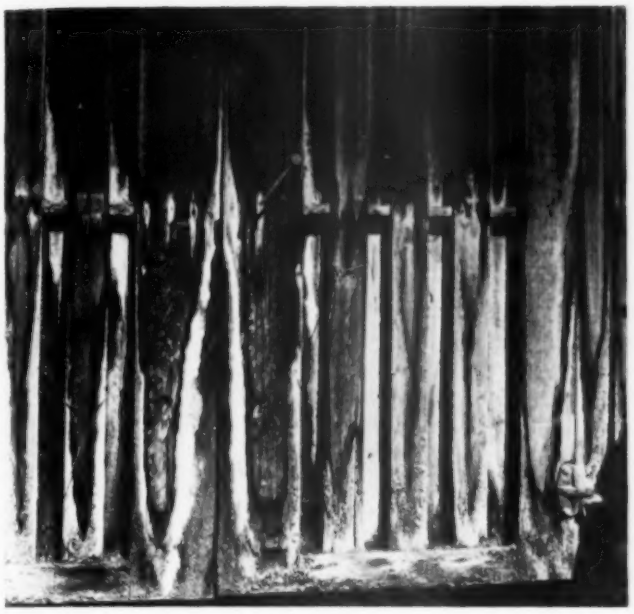


Fig. 4—Sodium carbonate, particularly, reacts with lignins, tannins and cellulose products to rot out wood.

This treatment usually delivers a water that is satisfactory for cooling at temperatures found in the average cooling system.

Sodium Zeolite Softening

Many industrial plants in the Midwest and on the West Coast use sodium zeolite for the makeup water to their cooling systems. Operators of these plants are enthusiastic over the high heat transfer efficiency obtained and the trouble-free performance of the systems.

Sodium zeolite softening ranks as one of the simplest treatments that can be used and requires the least amount of attention by the operators. But because of operating costs zeolite softening for cooling water makeup has not been favorably received throughout the country. Until recently, the cost of zeolite softening, because of the efficiency of the zeolite and the cost of salt, was usually more than the cost of softening with lime. However, with high capacity styrene base zeolite, capable of efficient operation at much lower salt requirements per kilograin of hardness removed, the difference between sodium zeolite and lime softening costs has become much less. Now the simplicity of the zeolite softening system compared to the cold lime treating system makes the sodium zeolite treatment much more attractive than it was previously.

Acid Treatment

Acid can be used to reduce the alkalinity and pH of the treated water to any desired point. The reduction of the alkalinity increases the pH_s of the water, reducing the tendency for scale deposition. Reduction of the pH of the water decreases the difference between the pH and the pH_s, which is of course decreasing the "Langelier Index" and again effectively slowing down the tendency toward scale formation. More important, the acid actually removes a certain amount of the carbonates in the water. If any calcium carbonate scale is to be formed, there must be carbonates in the water for this scale. Despite the indicated tendency of the water to deposit scale, it cannot do so if it does not have calcium and carbonates to deposit. Therefore, in lowering the carbonate content with acid, the amount of scale which can be formed is reduced as well as the tendency of the water to form scale.

If sufficient scale deposits out to reduce efficiency in the cooling system, the treatment may be varied or stopped until the scale is almost completely removed to the point where corrosion might again take place. This method of treatment, known as the "controlled scale" method, has been advocated by some engineers.

The formation of calcium sulfate scale was referred to previously. This chemical proves much more soluble than calcium carbonate but its rate of deposition is not greatly affected by changes in temperature. Therefore, with calcium sulfate the problem becomes one of keeping the calcium sulfate concentration below the maximum point of solubility. For normal consideration, this concentration should be under 1800 ppm, if the number of calcium ions is approximately equal to the number of sulfate ions. If the number of calcium ions, though, runs greater than the number of sulfate ions then the figure of 1800 ppm should be reduced. If the number of sulfate ions totals considerably greater than the number of calcium ions the figure of 1800 may be increased. Actually, it is better to determine the allowable concentration by considering it as a product of the calcium ions and sulfate ions.

Points of significance from the foregoing are:

1. Calcium hardness, alkalinity and pH should be reduced to limit the deposition of calcium carbonate scale. Lime treatment followed by acid usually proves adequate for this purpose, but in cases of very high calcium hardness, it may be found desirable to also feed soda ash.
2. Acid reduces carbonate content, pH and alkalinity.
3. Calcium sulfate scale formation can best be prevented by maximum reduction of calcium. This problem is not considered serious if the water is such that calcium carbonate will deposit first.

In most cases calcium carbonate scale would be likely to occur if raw water were used in the cooling system. However, as referred to previously, all waters to be used for cooling that show a considerable amount of sulfates should be checked for the possibility of calcium sulfate scaling. In many cases, a water of a high alkalinity and a comparatively low total hardness may be treated with acid alone to protect against scaling in the cooling system. But be sure the water permits this.

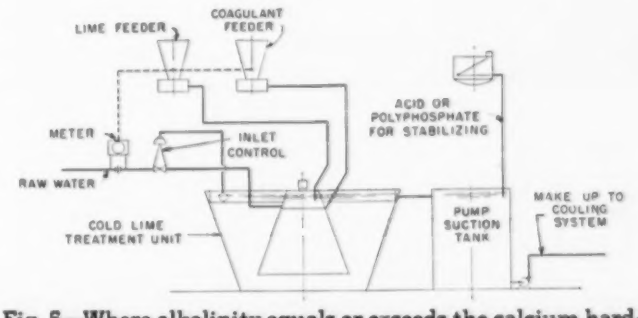


Fig. 5—Where alkalinity equals or exceeds the calcium hardness lime treatment followed by acid does well.

Corrosion, on the other hand, frequently can be minimized or eliminated by treating the makeup water to insure depositing a small amount of scale in the system. Again, the "controlled scale" method of treatment may be used to advantage.

Other Chemical Treatment

Other chemical treatments have also been found helpful. Sodium zeolite softening has worked well where part of the water is bypassed to provide a small amount of hardness in the makeup water. To some extent this also qualifies as a "controlled scale" method of operation. Chromates, polyphosphates and other chemicals can reduce or minimize corrosion.

The use of polyphosphates has been successful in some cases, and also polyphosphates have been used following lime softening to prevent after-precipitation and scaling in the cooling system. In these instances, the polyphosphates substituted for the acid which was previously discussed. It is difficult, however, to estimate the amount of polyphosphate needed and in most cases requires experimentation with it at the site to determine the dosage.

Vacuum deaeration of the circulating cooling water must be given consideration on some jobs. Vacuum deaerators reduce free CO_2 and dissolved oxygen without increasing the temperature of the water. This makes their use desirable for cooling systems, particularly where oxygen and CO_2 cause corrosion. In passing through the cooling tower, most of the free CO_2 is removed from the water (down to 2 to 3 ppm) but the water becomes saturated with oxygen. If steel tubes serve in heat exchangers and if high temperatures develop in some parts of the cooling system, corrosion may be a real problem and vacuum deaerators would be required.

Where mud and silt are present in the makeup water supply, coagulation and clarification can be effected without too much difficulty. In many cases the coagulation and clarification in a modern sludge blanket unit may be all that is required.

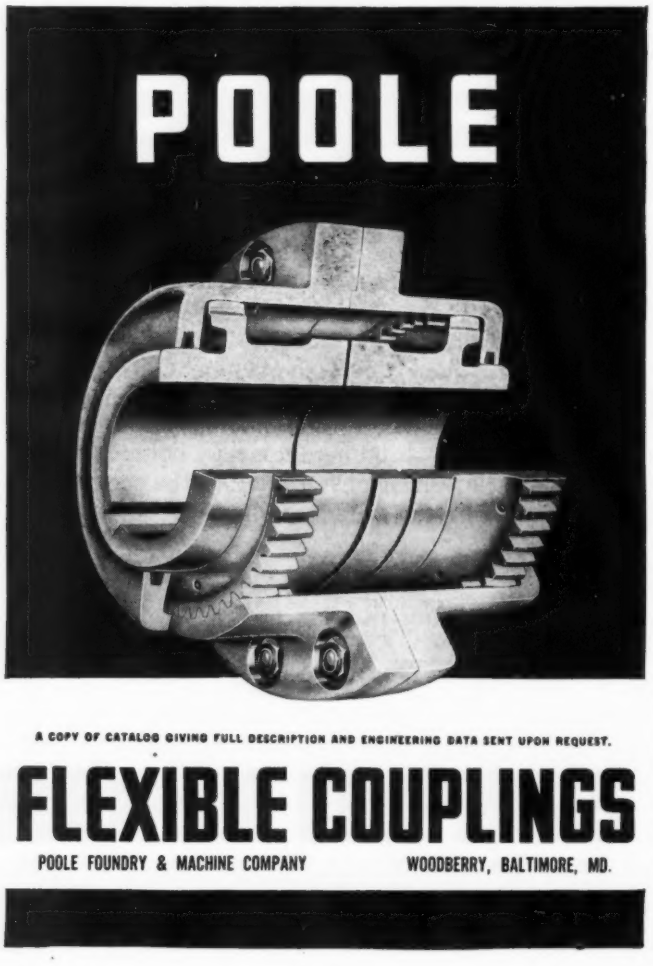
Algae and similar growths succumb to algicides now available for controlling or preventing slime and other growths. Chlorine is a well-known effective algicide for preventing slime growths but other algicides have certain advantages and may be used. Chlorine is usually fed intermittently and to some extent acts as a "shock treatment." Some growths seem to become immune to chlorine if it is fed continuously.

Summary

In order to intelligently consider a cooling water treatment problem, it is necessary to know the following:

1. Circulation rate in the cooling system.
2. Windage loss in the cooling tower.
3. Amount of cooling effected in the cooling tower (for determination of evaporation loss).
4. Maximum temperature of any point in the cooling system.
5. Analysis of the raw water to be used for makeup.

Each cooling water system must be given individual consideration, and the selection and the decision for the type of water treatment to be employed must be studied.



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

Utility System Provides Cathodic Protection to Fleet

Rockland Light and Power Co., Nyack, N. Y., is supplying electric service to provide corrosion protection to about 150 merchant ships of the National Defense Reserve Fleet anchored in the Hudson River off Jones Point, New York.

Authorized by Congress in 1946 as part of an emergency standby fleet, the vessels are continuously inspected and preserved above the water line by specialized working crews of the Maritime Administration. This agency has also been delegated the responsibility of underwater protection against corrosion through cathodic application of 24 volt direct current to the ships' bottoms.

Far more economical than drydock and paint, the cathodic process is not harmful to human or marine life and insures underwater protection to the hulls. Small graphite electrodes have been laid on the river bottom beneath each ship and are connected electrically to rectifiers set up on the decks of selected vessels. A-c power to operate the rectifiers must be brought via submarine cable from the shore.

Four substations have been completed at intermediate points off New York Route 9W by Rockland Light and Power Company, totaling 200 kva. These substations will supply all the power requirements for cathodic protection, lighting and small power through the submarine cable to the ships as mentioned above.

Cathodic protection has been widely employed in natural gas transmission lines and has proved most effective where pipe lines run on river beds.

Plastic pipe is joined together in a continuous length on top of the ground before being lowered into the ditch. Weight of a 20-ft length of 3-in. pipe is approximately 23 lb.

Here is shown the final operation of joining two lengths of plastic pipe together. Solvent cement has been applied to the pipe end and the slip-sleeve coupling.

Plastic Pipe Installation

CORROSIVE well water will be conducted through Tenite butyrate plastic pipe, in one of the first industrial installations of its kind, by Carolina Power and Light Company at their new Wilmington Steam-Electric Generating Plant, Wilmington, N. C.

The plastic pipe line, more than a quarter of a mile long, will deliver water from its source to large tanks where the water is to be decarbonized. The water to be conducted is air saturated and contains a high percentage of carbon dioxide. In the decarbonization process, the air and gas will be dispersed and the water will ultimately be used for all facilities of the new generating station.

Extruded of Tenite butyrate plastic, the corrosion-resistant pipe line has an inside diameter of 3 in. The 20-ft lengths were joined together by slip-sleeve couplings and solvent cement which provide, in effect, welded joints. It was not necessary to thread any of the couplings or pipe. The speed with which the butyrate pipe was joined, and the ease with which it was handled, due to its light weight, made it possible to install the pipe line in less than half the time it would have taken with metal. Material costs were also considerably lower.

The plastic pipe line will be operated at about 50 psig and is buried 30 in. below the surface of the ground. Before covering the pipe with earth the line was satisfactorily tested up to 70 psig. The only special precautions taken in this installation occurred at the point where the pipe passed under a railroad. A reinforced concrete duct was laid and the plastic pipe run through.

The new Wilmington Steam-Electric Generating Plant, where the pipe line will be used, is to be the largest in the Carolina Power and Light Company system. Two generators capable of delivering 100,000 kw power each are to be installed. Plans call for completion of the first unit in 1954 and the second in 1955.

The plastic pipe installation was made under the supervision of Ebasco Services, Inc., New York City. Grinnell Corp., Warren, Ohio, supplied the pipe which was extruded by Busada Manufacturing Co., Maspeth, N. Y. Tenite butyrate plastic is marketed by Eastman Chemical Products, Inc., Kingsport, Tenn.

After the pipe has been joined together on the ground it is pushed to the edge of the ditch prior to being lowered.

It was necessary to cut the last length of the plastic pipe to fit. An ordinary hand saw was used for this purpose.

Economic Utilization of Waste Heat from Slag-Tap Furnaces*

By DR. ING. RICHARD DOLEZAL Ostrava, Czechoslovakia

This article is based on research carried out in a European steel plant. The slag-handling equipment is designed to operate at low pressures, particularly in condensing plants. Under the conditions described the recovery of heat from slag is economic whenever the heat loss in the slag exceeds one-half per cent.

ECONOMIC utilization of the waste heat contained in the molten slag of slag-tap furnaces is a difficult task, particularly if the coal has a very high ash content.

The average heat lost in the outflowing molten slag, assuming that about 50 per cent of the ash with a melting temperature of 2200 F is caught in the slag-tap furnace, is:

Ash Content, %	Heat Loss, %
15	0.7
30	1.5
50	3.0

The loss values are given as percentages of the lower calorific value of the fuel. If the remaining 50 per cent of the ash is also returned to the slag-tap furnace from later passes of the boiler and the dust collectors, the heat losses increase to double the values given above.

The large quantities of water required for slag freezing become contaminated by a sludge of very fine slag particles and this is also very unfavorable. Recooling of the water in tubular heat exchangers is impracticable because the slag particles contained in the water are hard as glass and their erosive effect is very strong, leading either to quick perforation or to clogging of the tubes. Leakage is particularly dangerous because the slag particles gain access to the heated medium which is usually feedwater.

*Translated by E. Gros, London, England.

Description of Plant

In the following, a new type of plant is described in which the heat content of the molten and outflowing slag is utilized for heating the feedwater by means of low-pressure vaporization. The equipment is designed mainly for condensing plants where water is in short supply, and it is incorporated in a recently built boiler installation having a capacity of 485,000 lb of steam per hour and operating at 1690 psi.

A diagrammatic representation of the equipment is shown in Fig. 1. This has been designed for a heat input of about 4,000,000 Btu per hr in the slag. The slag flows out continuously through an open tap hole from the slag-tap furnace and is frozen and broken into small pieces by quenching sprays produced by circulating water of a temperature of 158 F. The slag particles are accumulated at the bottom of the slag tank and are removed after the tank is filled by a special device provided for this purpose. The gas pressure in the slag tank above the water level is equal to the pressure of the flue gases in the furnace, which is approximately the same as atmospheric pressure. The circulating water is heated by the freezing slag, and due to the contact with the water the hot slag particles in the slag tank are cooled. On the average the temperature of the circulating water increases by 9 deg F, i.e., to a temperature of 167 F. This increase in water temperature is determined by the quantity of the circulating water coming to the quenching sprays which is 440,000 lb per hr. A circulation pump draws the heated water from the slag tank into a low-pressure evaporator in which the pressure is maintained so that the boiling point of water is 158 F (i.e., about

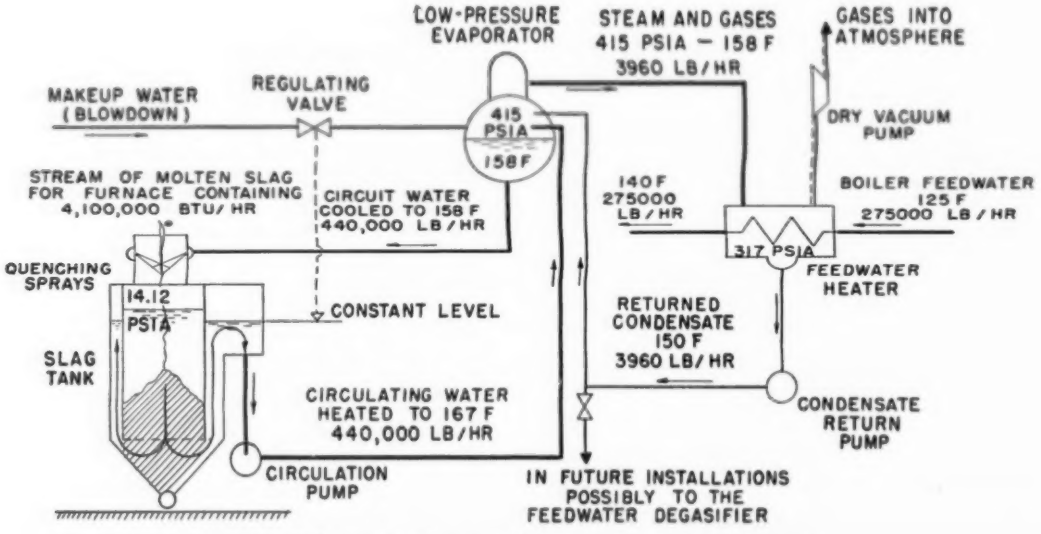

LOW-PRESSURE EVAPORATOR
STEAM AND GASES 415 PSIA — 158 F 3960 LB/HR
GASES INTO ATMOSPHERE
MAKEUP WATER (BLOWDOWN)
REGULATING VALVE
415 PSIA
158 F
DRY VACUUM PUMP
STREAM OF MOLTEN SLAG FOR FURNACE CONTAINING 4,100,000 BTU/HR
CIRCUIT WATER COOLED TO 158 F 440,000 LB/HR
140 F 275000 LB/HR
BOILER FEEDWATER 125 F 275000 LB/HR
317 PSIA
FEEDWATER HEATER
QUENCHING SPRAYS
14.12 PSIA
CONSTANT LEVEL
RETURNED CONDENSATE 150 F 3960 LB/HR
SLAG TANK
CIRCULATING WATER HEATED TO 167 F 440,000 LB/HR
CONDENSATE RETURN PUMP
CIRCULATION PUMP
IN FUTURE INSTALLATIONS POSSIBLY TO THE FEEDWATER DEGASIFIER

Fig. 1—Schematic diagram showing slag-tap equipment

4.5 psia). Consequently, the water at 167 F begins boiling in the evaporator and gets cooled down to 158 F. The released heat evaporates a part of the circulating water and the remaining recooled water is returned to the quenching sprays.

The steam produced in the evaporator and the gases expelled by boiling from the circulating water are fed into a noncontact heat exchanger where the vapor condenses with feedwater. The gases are removed into the open air by means of a vacuum pump. The heat exchanger is included in the steam cycle of the power station in advance of the lowest stage of feedwater heating.

The condensate is returned from the heat exchanger to the low-pressure evaporator by a condensate pump.

Provision for Makeup Water

The water loss of the circulation cycle must be replaced and makeup water is supplied to maintain a constant water level in the slag tank. The makeup water is fed into the low-pressure evaporator. An interesting feature of this system is that the makeup water can be hotter than the circulating water, because it cools down in the low-pressure evaporator by boiling in the same way as the circulating water does.

In the project described the alkaline blowdown from the evaporators of the steam cycle is used as makeup water to replace water losses of the circulating water. The largest water loss occurs during removal of the slag from the slag tank.

Nonuniformities in the heat input into the circulating water due to nonuniform flow of the slag from the furnace are compensated for by heat accumulation in the water volumes of the low-pressure evaporator and the slag tank.

The novelty of the system is that the heat content of the slag is transferred first to the circulating water, the quantity of which can be chosen to suit the particular requirements of the installation. This water gives up heat by evaporation at subatmospheric pressure, and the heat carrier is thus steam which is free of solid particles and contains only gaseous contaminants. The steam condenses in a noncontact heat exchanger and gives up heat to the feedwater.

It is therefore possible to design all parts of the system so as to prevent any damage due to erosive action of the solid particles in the circulating water and also to reduce the danger of clogging. Also, it is no longer necessary to use tubes of small diameters and unfavorable velocities of the circulating water, as would have to be done if the heat were transferred directly from the circulating water to the feedwater in tubular heat exchangers. Contamination of the feedwater by the circulating water is not possible if this system is applied, because only the steam generated in the low-pressure evaporator gets into contact with the surfaces cooled by the feedwater.

The whole system is composed of elements used in standard practice and it appears quite unlikely that unforeseen difficulties will occur in service.

It is contemplated that in future installations the condensate obtained from the low-pressure evaporator will be used directly as boiler feedwater after thorough degassing, provided this condensate will be satisfactory for the purpose. The plant is therefore designed to obtain very clean steam from the low-pressure evaporator which was previously described.

Mechanical pollution of the steam is counteracted by making the steam space in the low-pressure evaporator large enough and also by retaining the moisture of the steam by mechanical means. The fine slag particles contained in the circulating water cannot cause foaming in the low-pressure evaporator because these particles are always larger than the colloidal size.

Steam Contaminants

The steam generated in the low-pressure evaporator will, however, be polluted by gases because the circulating water in the quenching sprays gets into close contact with the flue gases of the furnace on a relatively large contact surface. As a result of this CO_2, SO_2, and possibly also SO_3 from the flue gases become dissolved in the water. The SO_2 and SO_3 are neutralized immediately and permanently, partly owing to the residual hardness of the circulating water and partly by the alkaline salts which are present.

The dissolved carbon dioxide is also neutralized by the alkalinity of the circulating water or may remain in the water as free carbonic acid.

If the slag contains a high percentage of FeS, the circulating water should always be kept alkaline to prevent formation of HS.

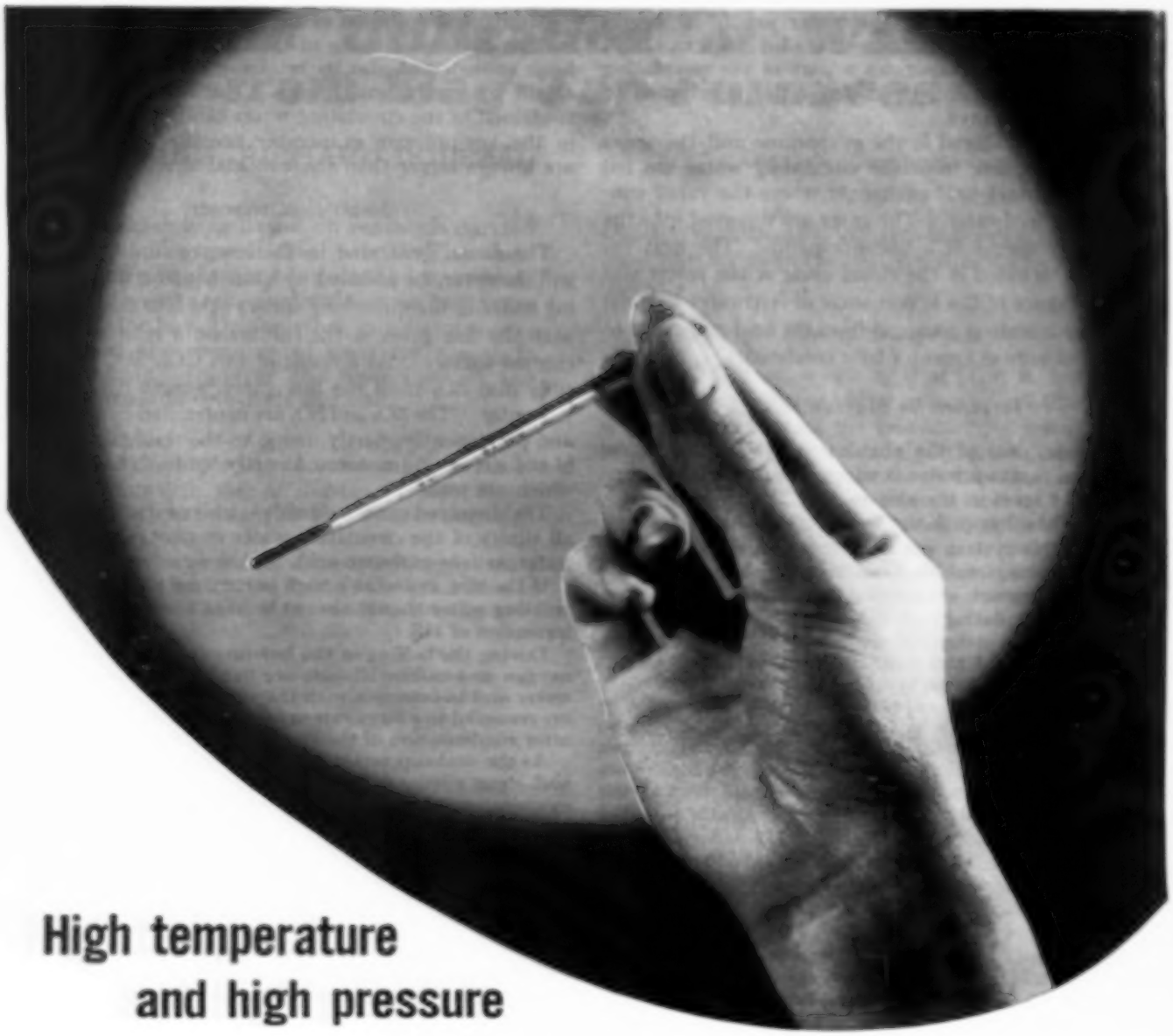
During the boiling in the low-pressure evaporator only oxygen and carbon dioxide are liable to escape from the water and to intermix with the steam. Both these gases are removed to a large extent by means of a vacuum pump after condensation of the steam in the heat exchanger.

As the makeup water contains alkaline and other salts and clean condensate is removed from the low-pressure evaporator, the circulating water gets enriched with solid particles. It is not, however, necessary to blow down a part of this circulating water because the water loss which occurs by periodic removal of the slag from the slag tank is sufficient for this purpose.

Summary

The system described has many advantages which may be summarized in the following terms. It is possible to utilize the heat content of the slag for heating the feedwater without the necessity of circulating dirty, slag-polluted water in tubes of a heat exchanger, the walls of which are in direct contact with the feedwater. There is no consumption of fresh cold water. The losses of the circulating water are replaced by introducing blowdowns into the low-pressure evaporator. The low-pressure evaporator of the system enables clean condensate to be obtained from the circulating water contaminated by solid particles. Production of a condensate of satisfactory quality from the circulating water is useful for easing the load of the evaporator and the softening plant of the steam cycle. Intensive circulation and large volume of the circulating water compensate the effect of the fluctuating heat input due to the nonuniform outflow of the slag from the furnace, and it is thus possible to keep the temperature of the circulating water high without fear that the water may boil in the slag tank.

With the present prices of coal and the necessary equipment in Czechoslovakia, utilization of the waste heat contained in the outflowing slag is an economic proposition if the heat loss in the slag exceeds one-half per cent based on the lower calorific value.



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Corrosion and Deposits in Regenerative Air Preheaters

THE U. S. Bureau of Mines recently released a report on a joint five-year investigation by that bureau and the Air Preheater Corp. dealing with corrosion and deposits in regenerative air preheaters (Ljungstrom type). Both laboratory and field studies were made, the latter on a multiple-retort stoker-fired unit at the Harding Street Station of the Indianapolis Power & Light Co. which was a party to the study.

Both deposit buildup and corrosion were investigated. Involved were sixty-six different plate materials, samples of which were observed under regular operating conditions, as well as laboratory tests of corrosion rates under various conditions of sulfuric acid attack. "Cor-Ten steel," a low-alloy material, was chosen arbitrarily as a standard for reference in the corrosion studies and the other materials compared with it on a percentage loss-of-weight basis. The relative corrosion rates are shown in the accompanying diagrams.

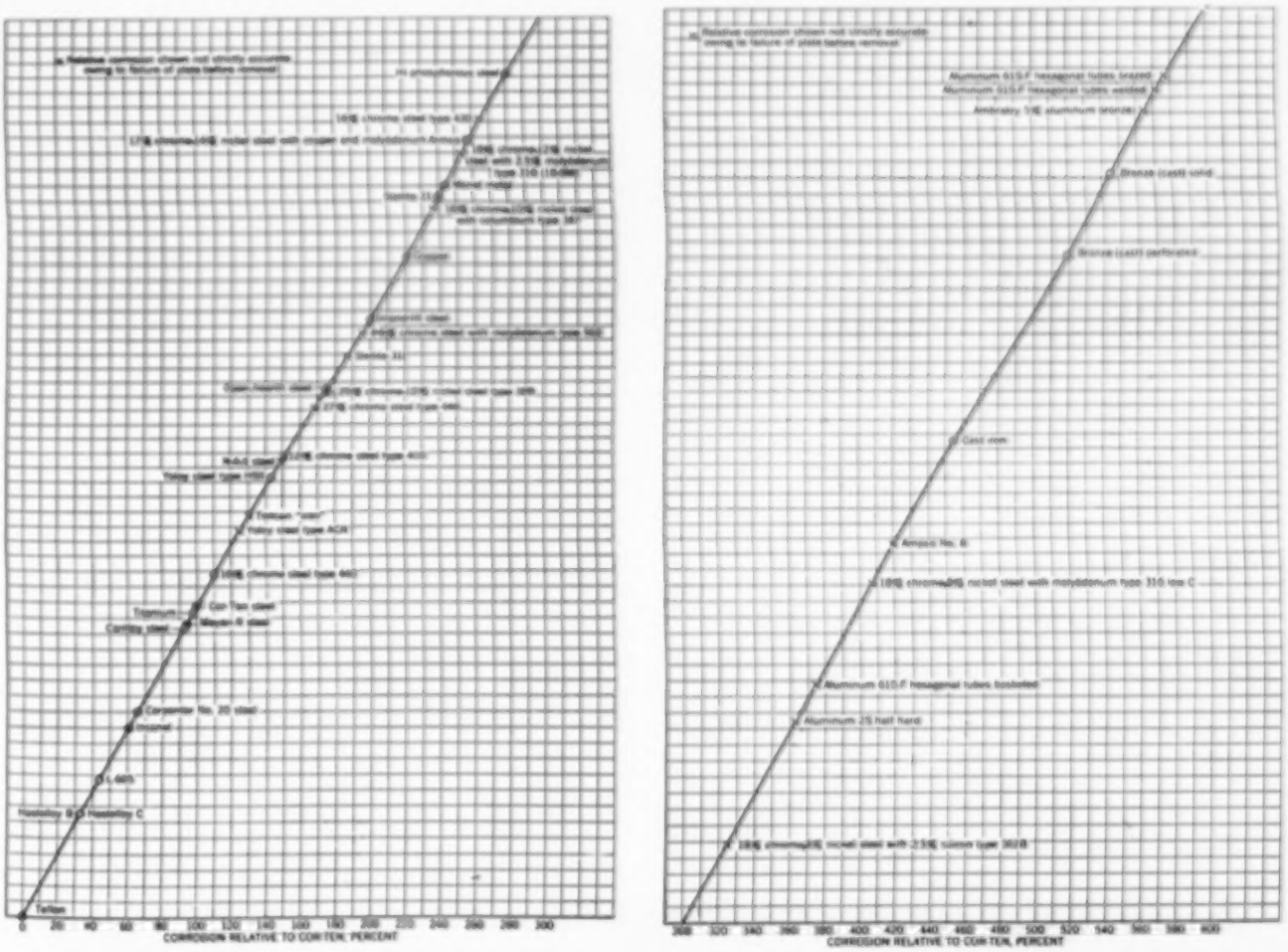
These show that six materials were substantially more resistant to corrosion than Cor-Ten. They were Teflon (a plastic), Hastelloy B, Hastelloy C, L 605, Inconel and Carpenter No. 20. All the high-alloy steels tested, with the exception of Carpenter No. 20 had higher corrosion rates. The corrosion rate of cast iron was about 4½ times that of Cor-Ten and 2½ times that of ordinary open-hearth steel. With the exception of Pyronamel, on enameling grade steel, none of 22 coated or plated test materials resisted corrosion satisfactorily. Pyronamel was not attacked, but the underlying steel corroded at points of imperfection of the covering.

In general, it was found that metals that form sulfates cannot be employed for air-preheater plates without corrosion and eventual plate failure. Such reactions proceed, to some extent, even at temperatures above the dewpoint of the gases.

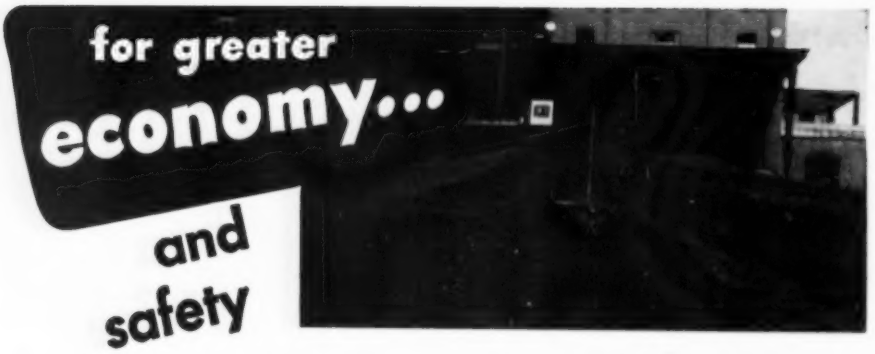
The tests showed that many factors, such as temperature, gas composition, the presence of deposits and their composition, as well as plate composition, affect corrosion losses.

Buildup of deposits on an air-preheater plate involves both physical and chemical actions. The former includes the trapping of fine dust particles by the plate surface which is seldom perfectly smooth, and the further trapping of larger dust particles by an accumulated deposit. The latter involves chiefly the formation of sulfates from acid reactions on the dust deposit and on the plate when it is not acid resistant.

The three predominant characteristics of all the deposits were partial solubility in water, the presence of sulfates, and acidity. The soluble part was mostly sulfates.



Relative corrosion rates of various materials compared to that of Cor-Ten steel



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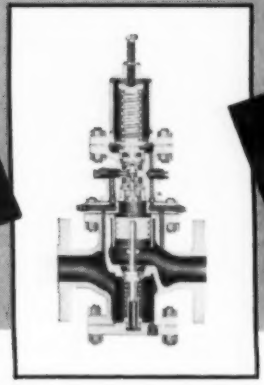

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In general, the deposits on the hotter parts of the heater plates, up to 3 or 4 in. from the top, or cold end, were thin and essentially inconsequential from an operating standpoint. At the cold top areas, however, the deposits readily built up in thickness.

The conclusions reached are that corrosion and deposits can be lessened by reducing the sulfur in the fuel. Prevention of the formation of SO_3, or the elimination of its chemical action, together with that of SO_2 would improve conditions greatly. Studies are now being made as to possible catalytic effects of substances such as iron oxide or vanadium in increasing the SO_3 content of the gases. Use of economical additives, such as $Ca(OH)_2$, $CaCO_3$ and $MgCO_3$, put in the fuel or blown into the furnace, offers promise and is now being investigated. The addition of ordinary fly ash from coal is being tried in oil-burning equipment. Use of cheap coatings, such as lime slurry, is being tested.

The report of this investigation, No. 4996, over the signatures of J. F. Barkley, Hilmer Karlsson, A. A. Berk, C. F. Stark and L. R. Burdick, covers 23 pages and contains 59 illustrations as well as numerous tables.

Business Notes

American Gas and Electric System recently reported placing its 14th major power plant in operation and its second within a six-month's span. The newest, Muskingum River station of the Ohio Power Co., a twin station of the Appalachian Electric Co.'s Kanawha River plant, started off with a 200,000 kw unit, first of an eventual 400,000 kw plant capacity.

Permutit Co. announced the building of a modern metalworking plant at Lancaster, Pa., scheduled for spring, 1954, completion. This new plant will consolidate the activities of the present Brooklyn, N. Y., and Philadelphia, Pa., buildings as well as serve as the new home for the **Simplex Valve & Meter Co.** products, now made in Philadelphia, Pa. Neither the main executive and sales office at New York, nor the Birmingham, N. J., plants will be affected.

The industrial division of **Armstrong Cork Co.** has formed one new department and consolidated two others to provide a more complete and specialized service for purchasers of friction, gasket and packing materials. A friction materials department will now handle problems in the power transmission and braking field while the new gasket and packing department will merge the affairs of the cork and rubber products departments.

Maintenance of Power Plant Equipment

AT the Fifth National Plant Maintenance and Engineering Conference held at the Conrad Hilton Hotel in Chicago on January 25–27, one highly successful session was devoted to maintenance of power plant equipment. The Plant Maintenance and Engineering Show was held at the same time at the International Amphitheatre, where more than 400 exhibitors had 5000 machines and products on display. Both events were produced by Clapp & Poliak, Inc.

General chairman for the conference was L. C. Morrow, consulting editor of *Factory Management & Maintenance*. He urged that plant personnel responsible for maintenance be open minded and of a searching disposition. They should be interested in equipment that can reduce the cost of plant upkeep and methods that mean short cuts. Among the topics covered at the conference were planning and scheduling of maintenance, work standards and incentives, maintenance in specific types of plants, sanitation methods, corrosion control, waste disposal, and maintenance cost control and budgeting.

Discussion

The leader of the discussion on power plant equipment was **W. C. Durning,** superintendent of utilities of the Organic Chemicals Division of Monsanto Chemical Co., St. Louis, Missouri. In his opening remarks Mr. Durning noted that in many industrial plants the power department is a cross between production and maintenance functions. In one sense it produces very important raw materials in the form of steam, electricity, air and other utilities. On the other hand it may be considered to be a service department in that it is of utmost importance that the service it produces and upon which the plant is entirely dependent must be supplied continuously, sometimes on an around-the-clock basis. In order to do this, it works out best for "power supervision" to control its own maintenance, especially since the equipment is usually heavier, causing the type of maintenance to vary quite widely from that of the production equipment in the average plant.

Outdoor Boiler Plants

Considerable interest was shown in problems of operating outdoor boiler plants. Several persons mentioned difficulties encountered in freezing conditions, particularly with instrument lines. In one plant in North Carolina where there are occasional drops below freezing it has been necessary to steam trace all pneumatic transmission lines. At another plant difficulty was experienced because a flow meter froze up and caused an unbalance of load on several of the boilers, nearly shutting down the entire plant. With hydraulic and air transmission lines special precautions must be taken to prevent freezing. Some types of antifreezes may be used with hydraulic fluids, while with air lines precautions should be taken to insure dried air. Silica gel was mentioned as one agent for drying air.

There is no doubt that operating personnel prefer indoor plants because of the problems of freeze-up. Notwithstanding this preference, it was mentioned that brickwork cost continues to be a deterring factor against the construction of fully enclosed boiler plants.

Burning Waste Fuels

Plant engineers from two sash and door manufacturing companies told of some of their problems in burning wood waste from these operations. Both had achieved satisfactory results in their boiler plants but only after a considerable amount of experimentation. Mention was made of the problem of burning wood waste in the Pacific Northwest where salt water contamination is a complicating factor in design and operation.

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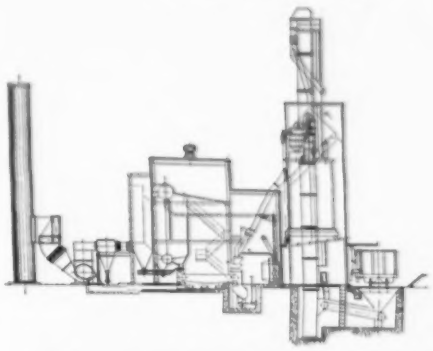

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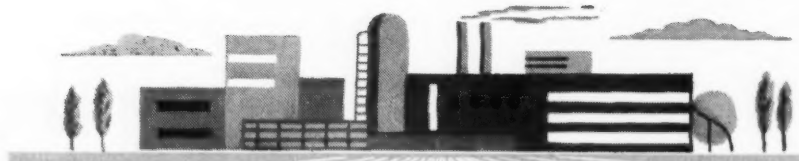

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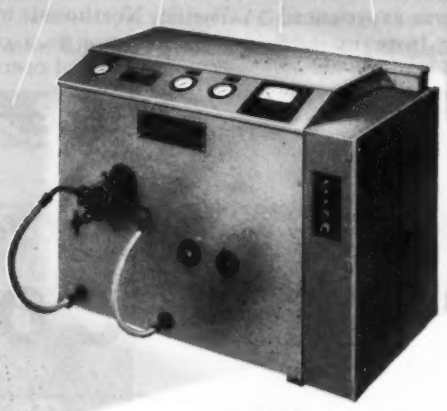

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Removing Fireside Deposits

Several of those present revealed that they were beset with problems with removing fireside deposits from spreader-stoker-fired water-tube boilers. The consensus was that if such deposits had built up appreciably the only way to remove them was manually. There are, however, certain additives commercially available which will tend to reduce the rate of deposit accumulation. These are used with varying success but probably have their most successful application on small units where the loads are not too great. In several plants it was reported that a steam lance is used to remove such deposits. Mention was made of the danger of blow back from a plugged-up steam lance although it was felt that most operators are sufficiently safety conscious to avoid difficulties of that sort. Lancing with cold water at rather high pressure is another method that is in rather wide use.

Stoker Operation

The controversial matter of reinjection of spreader-stoker fly ash at high rating was discussed at some length. One engineer mentioned that his plant had a spreader-stoker-fired boiler equipped with a mechanical collector which when operated with full reinjection was able to meet a rather stringent smoke ordinance within a large metropolitan area. Reinjection has disadvantages in terms of possible erosion of pressure parts which may offset costwise the increased efficiency derived from its application. One engineer expressed the belief that effects of reinjection are at present not fully understood and that more research on this subject is needed.

In connection with spreader stoker operation in a plant in a Southern tobacco-growing region, mention was made of complaints from farmers who found deposits of fly ash on tobacco leaves. Upon investigation this was found to be caused by faulty distribution and no difficulty was experienced after baffling was changed to insure uniform distribution.

Boiler Inspection and Useful Service Period

Several engineers were concerned with state inspection requirements. In some instances boilers must be inspected annually even though their condition may be such as to warrant less frequent inspection. However, very few industrial plant boilers are operated for such long periods as to be adversely affected by state inspection requirements.

In anticipating lower loads in some

plants a question was asked concerning the comparative merits of wet storage versus dry storage of boilers. Experience of those present was about equally divided and there seemed to be no strong preference for one method over the other. There are some advantages and disadvantages in each method, and the choice appears to be pretty much an individual plant matter.

A question was raised concerning the potential life of water-tube boilers. There was no general agreement as to the economic life of such units.

Air Compression and Distribution

More interest was shown in the topic of air compression and distribution than any other subject discussed during the session. Experience with carbon-ring compressors at several plants varied widely, some engineers finding them quite satisfactory, while others reported considerable difficulty. With reciprocating compressors the matter of removing water and oil from compressed air is a continuing problem. At least one engineer recommended the use of centrifugal-type compressors for overcoming the problem of entrained oil and air.

At one plant having a very extensive air distribution system it was found that the use of discarded flow-operated steam traps proved quite satisfactory. Another plant engineer advocated the use of driers and air receivers as a means of overcoming some of the problems of condensation in air lines. In a plant where the air system is operated intermittently the practice is to blow down the lines until the air is dried.

There are some plants in which air systems serve both the process and instrument needs. In most instances better quality of air is necessary for instrument than for process use.

There was considerable discussion of air distribution pressures for industrial plants. Among those present there was a very wide variation in the pressures used, including several plants having a multi-pressure system. The appeal was made that the equipment manufacturers should consider establishing standard inlet pressures for air-operated tools analogous to the standard voltages used for electrical installations.

Power Generation

A question arose as to when it pays to generate industrial power. One engineer stated that this depends on conditions. In cases, for instance, where a plant uses substantial quantities of steam for process at 125 psig or lower, boilers can be operated, for example, at 675 psig, 750 F. Back-pressure turbine-generators or sizable turbine-mechanical drives, if applicable, can be used to reduce the pressure to perhaps 125 psig at 100 deg F superheat, which steam can be used for process.

If applicable, some of this 125 psig steam can be used to drive reciprocating engines or turbines which in turn can operate air compressors or any other mechanical drives for which a plant may have use. These low-pressure steam drives can exhaust at 3 psig, which steam can be used for building and feedwater heating. In dropping from 675 to 125 psig about one kwhr can be generated by every 30 lb of steam flow, and the heat chargeable is equal to that of slightly more than 3 lb of steam per kwhr. If a relatively large mechanical unit can be operated directly by a 675-psig turbine, development of mechanical horsepower hours, delivered to the shaft, should be even more economical because investment in the electric generator, switchgear, substation equipment and transmission lines would be avoided. Fixed costs such as interest on the capital investment, taxes, labor costs, etc., must, of course, be taken into consideration. In any case where a plant uses large quantities of steam in process a study involving the installation of by-product power generation is definitely worth while.

Steam Turbine Inspection

Discussion of the time to open steam turbines for inspection disclosed that some plants operate machines for as long as five years without complete internal inspection. While other plants make annual turbine inspections, there were several present who believed that initial turbine operation should be for two years after which turbine inspections should be made on the basis of operating judgment.

In standby turbines, more frequent inspection may be necessary because of the corrosion problems that arise from intermittent operation. At one plant which is dependent upon transmission lines subject to occasional outages, there are standby turbines on each piece of vital equipment. Even though these machines are turned over regularly considerable difficulty is experienced on account of corrosion.

Power Plant Maintenance Crews

Many plants have separate crews for power plant maintenance because of the specialized type of activity, and those present were definitely in favor of maintaining such separate crews. However, they did feel that there should be, and in general was, coordination of efforts of both power plant and general maintenance activities.

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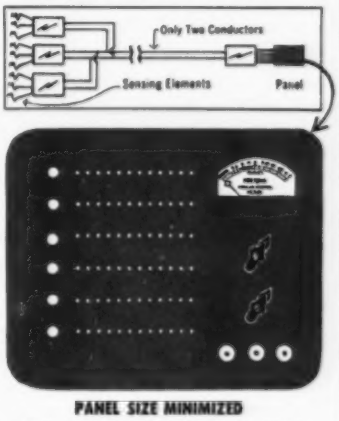

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Dehydration Units

Packaged dryers, known as the Hydryers, for reduction of moisture contents of compressed air or, for that matter, other gases to low dewpoints or concentrations make up the subject matter of the J. F. Pritchard & Co., 8-page bulletin, 16.0.081. In this bulletin are discussions of the equipment's fundamental operation, size ranges, construction, controls, special models in addition to basic flow diagrams and equipment selection data.

Automatic Speed Control

The full gamut of uniform temperature, pressure, liquid level and flow control plus many of the problems of automatic production control, such as tension, acceleration and deceleration, velocity at peripheral speed, and synchronization are dealt with in the 24-page bulletin, G-537, now available from the Reeves Pulley Co. Heart of the company's bulletin are its two principal units, the Variable Speed Transmission and the Vari-Speed Motodrive, and coupled with one or both is a choice of one of eight automatic controls—hydraulic, pneumatic, mechanical automatic, "auto-tens," that is, automatic tension, controlled acceleration, differential, electric remote, and the company's Conoflow, a special combination of pneumatic controls with a Vari-Speed Motodrive.

Closing Valve

A special descriptive, 6-page brochure has been released by the Simplex Valve & Meter Co. to illustrate their type CCAV, controlled closing valve. This valve has been designed to prevent surge and water hammer, to control speed of line closure, and to vent air. If necessary to prevent damage the valve discharges water and admits air to prevent pipe collapse from line breaks.

Liquid Precipitator

From the early design of the C. H. Spaulding precipitator, Permutit Co. has developed its own precipitator, featured in a recent 20-page bulletin, No. 2204B. This device removes liquid impurities by precipitation, adsorption, settling and upward filtration. Ground space savings are said to be as much as

50 per cent over other methods and accompanying chemical savings are put at from 10 to 40 per cent. Chief uses are in water softening, removal of turbidity, color, taste, odor, alkalinity, silica and fluorides.

Specialized Instruments

A condensed 4-page bulletin has been made available by the F. W. Dwyer Mfg. Co. to present the company's line of combustion, draft, pressure, flow, vacuum, CO_2, smoke, velocity, static pressure, pressure differential and temperature gages.

Automatic Filters

An illustrated 12-page bulletin, No. 500, released by the Dollinger Corp. contains specifications, engineering and performance data for a wide range of sizes for the large air volume, high efficiency, Staynew automatic filters.

Chemical Cleaning

A special bulletin release by Dowell, Inc. covers scale removal from water and gas lines plus a magazine reprint on condenser cleaning. The material gives specific how-to information and some data on chemical quantities and costs.

pH Control

A complete system for continuous, automatic control of pH in slurries, industrial wastes, and clarified solutions is explained in the Industrial Div., Minneapolis-Honeywell Regulator Co. Instrumentation Data Sheet 9.6-5a. The system is designed for use with dry chemical feeders.

Control Instruments

Instrument specifications for a range of process control equipment including flow meters, recorders, controllers, pressure regulators, sight flow indicators, and chemical feeders make up the bulk of a two-color, 20-page catalog, No. 2 issued by the Fischer & Porter Co. Sizing nomographs for the two most common types of Flowrater meters are given covering both liquid and gas service.

Heating Catalog

The 60-page, two-color, 1954 edition of General Electric Co.'s catalog on Calrod electric heaters and heating devices, GEC-1005E, is now available. It covers application, special features, installation and pricing with 175 photographs and drawings to illustrate the various products. An index by processes and applications helps locate specific equipment. Power requirements and heat losses also are listed for many applications.

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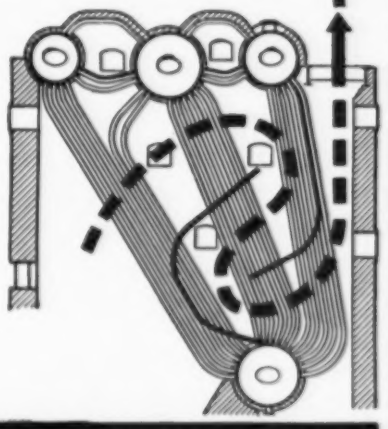

THE ENGINEER CO.
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Water Sampler

A specialized heat exchanger unit, the Paracoil boiler water sampler cooler, No. 75, makes up the subject matter of a 4-page illustrated bulletin released by the Davis Engineering Corp. Design specifications along with a set of charts to determine cooling water flow rates for different sample temperatures and several typical piping hookups comprise the information furnished.

Recorder Controller

In the 4-page technical data bulletin, F-452 M, the Fielden Instrument Div., Robertshaw-Fulton Controls Corp., describes the design and construction features of its multi-point circular chart recorders which, through a special chart unit drive, become either a 24, 48, or 96 point multi-record system.

Stanton Balances

Four models of the precision Stanton chemical and non-chemical balances are pictured in a 4-page bulletin, No. 329, recently released by the Burrel Corp. Features of the line described in the bulletin are air dampening cylinders which dampen weighing beam motion rapidly and planes of synthetic sapphire (corundum) which provide a uniformly hard surface for continued sensitivity.

Ion Exchange

A new 16-page illustrated bulletin, Amberlite Ion Exchange, put out by the Resinous Products Div. of Rohm & Haas Co., covers fundamentals of ion exchange for the novice or those needing a refresher. The basic ion exchange processes are described with aid of a full page of two-color drawings and the early history of synthetic ion exchange resin development appears in the introductory section.

Water Gage Television

The bulletin WG-1813 covers the equipment employed in televising boiler water level gages now available through Yarnall-Waring Co. The equipment includes TV camera, illuminator, monitor, all necessary linkage. Auxiliary viewing monitors are also available.

Steam Trap

A new inverted bucket trap, the Super-Silvertop Heat-Kwik, said to vent air from steam units eight times as fast as ordinary inverted bucket traps is featured in a 4-page bulletin, No. 1153, recently released by V. D. Anderson Co. A large diagram shows how this trap obtains such fast air releases and pictures the role of the two separate orifices, one for condensate and a different one for air.

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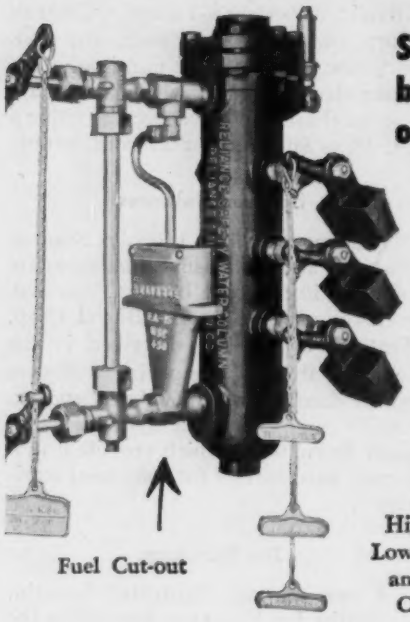

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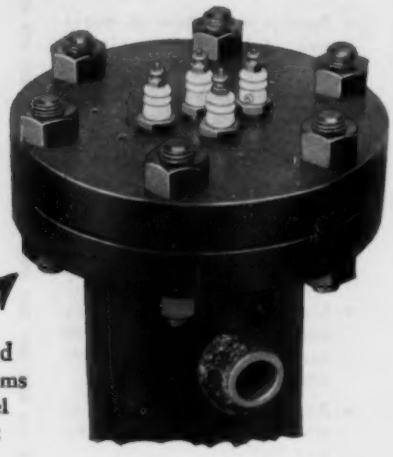

High and Low Alarms and Fuel Cut-out

Using isolated circuits of low amperage, the new electrode-type Reliance Levalarms avoid troubles usually encountered with water level alarm and fuel cut-out devices. Without bellows or stuffing boxes; without vacuum tubes or magnets, these controls take their commands direct from the boiler water itself as it rises or falls in the water column.

One style adds the facility of a positive fuel cut-out control to float-operated whistle alarm columns. Other models provide high and low alarm *and* fuel cut-out facilities, and pump cut-in and cut-out if desired. In some instances the new Levalarms can be added to water columns already in service. Their installation is easy for any engineer. Write today for Bulletin D2 covering Electrode-type Levalarms.

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Scanning System

Self-monitoring electronic scanning that drastically cuts cable and installation costs for equipment instrument monitoring is claimed to result from an electronic switch developed by the Kybernetes Corp., 1108 Raymond Blvd., Newark 5, N. J.

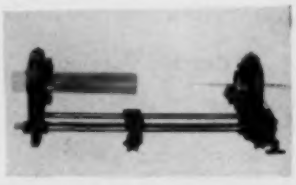
On the indication panel are rows of labelled miniature lights preset with different alarm limits. When a limit is exceeded a horn sounds, and point and zone lights on the panelboard light up. The operator turns off the horn, and turns on the zone and point switches to the indicated zone and point so the meter will register the condition at the alarming sensing element. During this or any other logging of points the scanning and alarm indication continues uninterrupted.

Solenoid Valves

A new development in the Automatic Switch Co., Orange, New Jersey, line of 3-way solenoid valves, their special bulletin 8300, ASCO valves, are constructed with either steel or stainless steel bodies. Both types have stainless steel trim throughout and are designed to handle a wide variety of gases and liquids usually corrosive to bronze, brass and cast iron. When equipped with high temperature coils the valves will take hot gases up to 450 F. Pipe size is 1 in. and port orifices (five in number) are $^1/_8$ to $^3/_8$ in. with maximum pressure, 1000 psig.

Glass Lathe

Specialized glass work in the laboratory and certain production operations such as making ring seals, tees, flanges, tapers, glass fusings and a variety of repairs can be handled with the Lab-Lathe, manufactured by Bethlehem Apparatus Co., Inc., Hellertown, Pa. It features a unique, sleeve-grip chuck that permits quick set-ups of almost all forms of glass work.



Tubing of any length, up to 100 mm dia., can mount through the spindle. Extension bars grip a variety of glass shapes in sizes up to 12 in. dia. with eccentric settings as required. Length between chucks is 36 in., radial clearance, 8 in., and through-spindle diameter, 6 in. Net weight is 150 lbs.

Steam Metering

Widely different steam load conditions can be metered by means of an engineered equipment package built around a dual range meter system developed by Builders-Providence, Inc. 345 Horns Ave., Providence, R. I., in conjunction with C. E. Squires Co., 15802 Syracuse Ave., Cleveland 10, Ohio. The principle involved is a division of flow from a high range to a low range Shuntflo Meter whenever system demand falls off. The arrangement is said to (1) increase annual revenue from steam-using customers or departments, (2) prevent overloads and subsequent damages to low range steam meters, (3) eliminate need for condensate meter with return lines, (4) save the need of changing meter orifices.

High-Heat Paint

Where high heat is a problem to metal finishes Tropical Paint and Oil Co., Cleveland 2, Ohio claim their high-temperature paint product, Thermalite, does a first class surface protection job for a temperature range of 400 to 1000 F. Formulated with a special heavy silicone content it is said not to discolor, blister, flake or burn off on manifolds or exhaust stacks.

Four-Wheel Drive Scraper

As a further development of the successful 4-wheel drive in the Euclid Div., General Motors Corp., Cleveland 17, Ohio, Twin-Power Scraper, the manufacturer has placed two experimental 4-wheel drive scrapers on construction projects in North Carolina.

The scrapers, rated at 18 cu yds struck measure, employ a 300-hp diesel engine mounted behind the scraper bowl to drive each of the four wheels. The unit has no tractor so that it is more maneuverable and can make shorter turns. Field tests on coal piles and the Ohio Turnpike indicate the scraper can self load many materials. No production is planned for 1954 until field tests are completed.

Thermocouple and Well

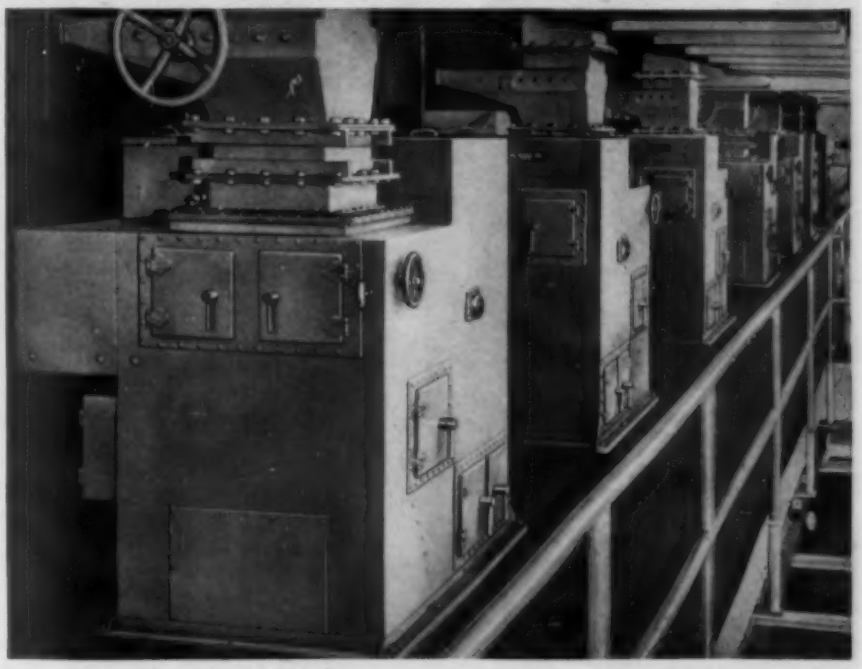
A new thermocouple protection tube, the LT-1, combining the thermal conductivity and shock resistance of metal with the oxidation and deformation

Delaware Power & Light

specifies

Richardson

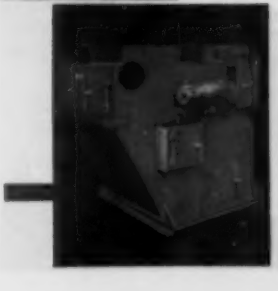
Like many progressive utilities, Delaware Power & Light Company selected Richardson Automatic Coal Scales to maintain a constant check on boiler efficiency in their new generating station. The bank of Richardson Model 39's shown now handles this responsibility.



To both industrial and utility power generating stations, specifying Richardson means—

1. A 24" x 24" inlet opening and 26" wide belt for maximum coal flowability.
2. All wiring and controls outside coal chamber.
3. Access doors which will not spill dust on floor when opened.
4. Beam ratio test facilities outside coal chamber.
5. Gravity operated by-pass, with no restriction of coal flow to downspout.
6. No drag links or wires attached to weigh hopper.
7. Nationwide after-delivery service.

Latest development in the 39 Series of Richardson Automatic Coal Scales is the Model H-39 shown below. May we send you our new 16-page engineering data book on the H-39 Coal Scale (Bulletin 0352), without cost or obligation?



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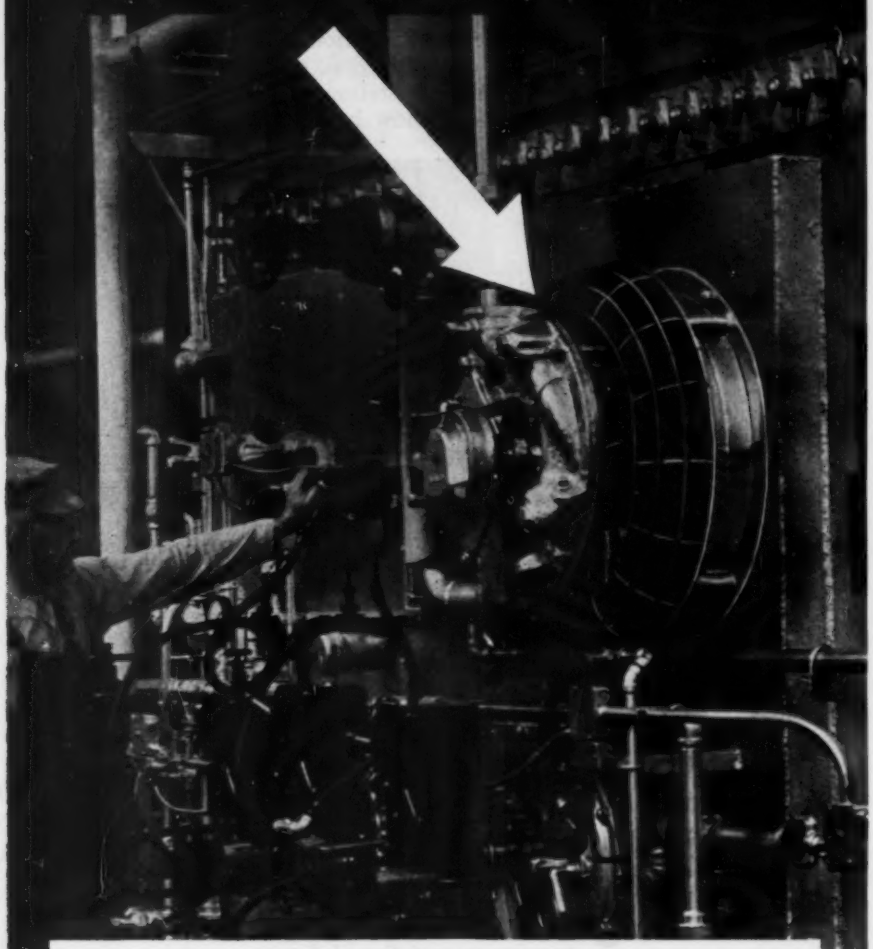
Richardson

MATERIALS HANDLING BY WEIGHT SINCE 1902

Only a WING Axial Flow Turbine Blower would permit such a compact installation



THIS neat, compact forced draft installation shows how the WING Axial Flow Turbine Blower can save thousands of dollars in installation costs by eliminating the duct work and excavation costs attendant on the use of other types of blowers. This compact, quiet, low-speed blower delivers 11,300 CFM at 3" static pressure to the 40,000 lb. per hr. B & W oil-fired boiler at the Chicago plant of Southern Cotton Oil Co., makers of the well-known Wesson Oil. This is the third Wing blower at the Chicago plant, the tenth in all Southern Cotton Oil plants, the first having been installed in 1916.

Wing

L. J. Wing Mfg. Co.

54 Vreeland Mills Road
Linden, N. J.
Factories:
Linden, N. J. and Montreal, Can.

resistance of ceramics has been announced by the Bristol Co., Waterbury 20, Conn. The thermocouple well has a wall thickness of only 1/8 in. so time lags in temperature are greatly reduced. The well material has a thermal conductivity about the same as cast iron.

Available in lengths of 12, 18, and 24 in. the metal ceramic well can also be supplied in a complete thermocouple assembly. Straight type, connection head extension type, and connection head angle type can also be had.

Vibration Detector

Highly sensitive, crystal-type accelerometer for use in measuring vibration accelerations up to 50 G's in large rotating apparatus has been announced by General Electric Co., Schenectady 5, N. Y. Its application is considered especially good for turbine generators, large motors, blowers, steam and gas turbines and centrifuges.

The critical elements, such as the barium titanate crystal stack and components, are shielded by a cup-shaped end mass which guards against loss of sensitivity in the most corrosive atmospheres. A stud-type mounting transmits forces directly to the crystal assembly, adding to precision and accuracy by reducing the possibility of erroneous outputs due to resonances of the mounting system.

The output voltage of the detector is proportional to the acceleration imparted to the equipment on which it mounts. This holds true, though, only in a direction perpendicular to the mounting plane. In addition to the detector assembly a properly calibrated amplifier, a rejection filter and an indicating instrument are furnished.

Yard Ramp

Light weight, portable ramp of magnesium fabrication with a raised, diamond-surface plate for rugged high speed material handling has a fixed wheel or hydraulic lift with adjustable 38- to 55-in. elevation so that trucks or cars can be loaded quickly from ground

level. The device manufactured by Penco Engineering Co., 25 California St., San Francisco 11, Calif., comes in two sizes, 60 in. and 70 in. wide, and in six capacities from 4000 to 16,000 lbs. It is said to need only a one-man operating crew.

Unit Heater

The motor mount has now been combined with an integral safety guard in certain sizes of the L. J. Wing Mfg. Co., Linden, N. J., unit heaters to give a more rapid mounting and greater guard strength. This construction change has been applied to both horizontal discharge and suspended, vertical discharge revolving unit heaters.

Air Heaters

A number of typical applications, in color, of the manufacturer's direct-fired air heater are presented in a 6-page bulletin No. 600-A put out by the Peabody Engineering Corp. They feature the adaptability of this equipment to the process industries, particularly for spray drying, liquid concentrating, rotary drying and petroleum refining operations.

Power Transmission Products

Recent 4-page brochure by Lovejoy Flexible Coupling Co. brings together in convenient reference form specifications, selection information, sizes and dimensions for (1) flexible couplings of spider and cushion types with a description of the different spiders and cushions available, (2) variable speed pulleys, $^1/_4$ to 8 hp size, (3) variable speed transmissions, $^1/_3$ to 5 hp, (4) adjustable and tilting motor bases, (5) universal joints.

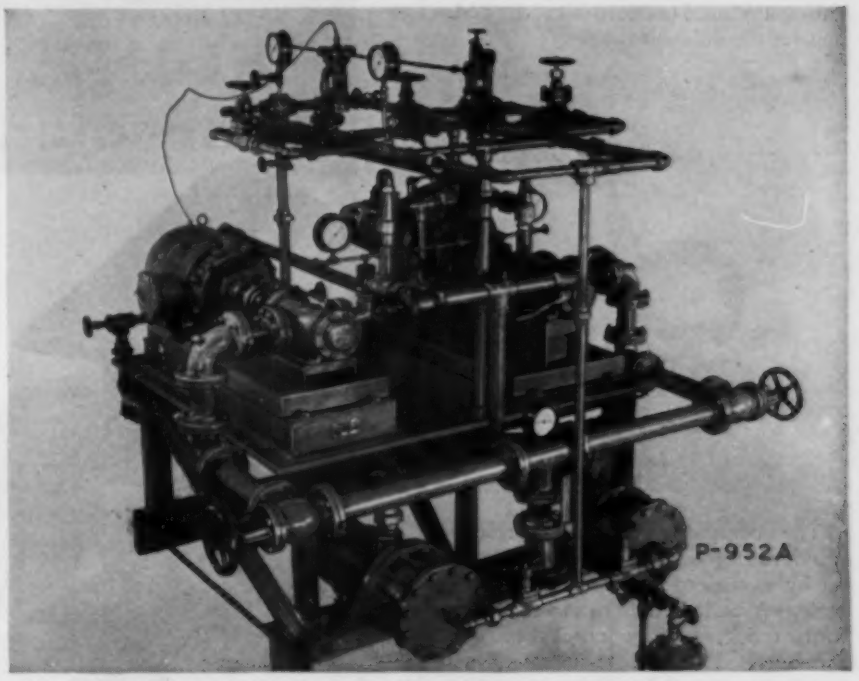
Manometer

Complete with tubing and fittings and housed in an attractive rugged molded plastic housing, a new manometer suitable for an air filter gage, static pressure indicator, draft gage or air velocity meter, the I-V Gage, has just been put on the market by the F. W. Dwyer Mfg. Co., 317 South Western Ave., Chicago 12, Ill.

The unit comes with ranges from zero to 3 in. water gage or zero to 7 in. water gage with a low range accuracy of 0.01 in. water. It is also available in a direct reading velocity model for use with a pitot tube, in ranges of 0–7000 and 0–10,500 feet per minute. The standard model is shown in photo above.

Now!

MORE COMPACT THAN EVER..



P-952A—Steam Turbine and Electric Motor drive gives flexibility in this compact Model P-E52H size No. 25 unit.

NATIONAL AIROIL

FUEL OIL PUMPING AND HEATING UNITS

NATIONAL AIROIL Fuel Oil Pumping and Heating Units are specially designed to prepare, for combustion, all grades of fuel oil including No. 6 or Bunker "C" Oil and residuums. They will draw fuel oil from above ground or underground tanks, preheat it to proper constant temperature and deliver it to Oil Burners at an even pressure, best suited for the burners. Our Fuel Oil Pumping and Heating Units are the result of years of experience. They come completely equipped ready for steam, exhaust, condensate, oil suction, oil return, and electrical connections. All valves, regulators, etc., are readily accessible. The piping arrangement is easily understood. These compact, space-saving units are available in a range of sizes and models in both Medium and High Pressure types. For complete details, write for our Bulletin 40 — very interesting and informative.

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DUAL STAGE, Combining Steam and Mechanical Atomization
LOW AIR PRESSURE OIL BURNERS
AUTOMATIC OIL BURNERS, for small process furnaces and heating plants
GAS BURNERS
COMBINATION GAS & OIL BURNERS
FUEL OIL PUMPING and HEATING UNITS
FURNACE RELIEF DOORS
AIR INTAKE DOORS
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SPECIAL REFRACTORY SHAPES

NATIONAL AIROIL BURNER CO., INC.

1310 EAST SEDGLEY AVE., PHILADELPHIA 34, PA.
Southwestern Division: 2512 South Boulevard, Houston 6, Texas

Hand Tachometer

A novel thumb-operated selector automatically changes the scale numbers for each speed range on the newly announced hand tachometer, now available from Metron Instrument Co., 432 Lincoln St., Denver 3, Colo. The same mechanism brings into view the correct number of rpm per scale division eliminating any need to figure out scale workings for the different ranges.

The computed capacitor principle provides freedom from damage brought on by overspeed or selection of wrong scale. A built-in calibration circuit affords quick, positive checks on performance. Different tachometers and range-extending adapters are available to measure speeds as low as 2 rpm and as high as 100,000 rpm.

Tube Rolling Control

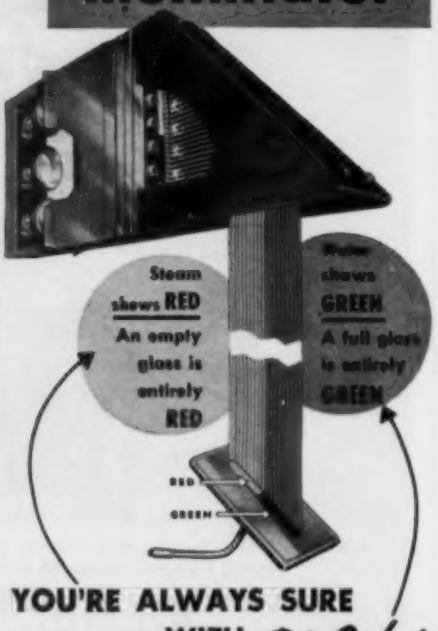
The combined advantages of air operation with the precise control of electric machines is claimed by Crane Packing Co., 407 South Dearborn St., Chicago 5, Ill., for this recently released electropneumatic tube rolling control. This device, equipped with an air motor of increased power and flexibility to give faster tube rolling of a wide range of ferrous and nonferrous materials, can handle ferrous tubes, for example, up to $2^1/_4$ in. O.D.

The manufacturer states the pneumatic-electric control is so exact that tube expansion into the sheet can be held to the desired tightness and holding strength for the service planned. Over-rolling dangers and cold work crystallization are said to be practically eliminated and distortion and fracture of tube ligaments prevented.

A-C Motors

A new line of well-protected, versatile, squirrel cage induction motors has been announced by Reliance Electric & Mfg. Co., 1088 Ivanhoe Rd., Cleveland 10, Ohio. The line, including protected and enclosed motors for all industrial purposes, meets the recently adopted standards of the National Electrical Manufacturers Assn.

DIAMOND BI-COLOR WATER GAUGE with "HI-LITE" Illuminator



YOU'RE ALWAYS SURE WITH Bi-Color

There is no guessing about boiler water level when you use the Diamond Bi-Color Water Gauge. It makes use of an unvarying optical principle (the difference in refraction between water and steam) to always show water green . . . steam red. With proper illumination, the water level is unmistakable . . . whether viewed directly . . . through a system of mirrors . . . or on control panel by the use of Diamond "Utiliscope" (Wired Television).

A big improvement over other light sources, the "Hi-Lite" Illuminator uses standard high-intensity lamps similar to automobile "sealed beam" headlights. The gauge will thus retain visibility with much longer time between gauge cleanings. Use the coupon below for further information.

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Essentials of Engineering Thermodynamics

By Herman J. Stoever

This is an abridged version of the author's earlier text, "Engineering Thermodynamics." Intended specifically for a one-semester course, the book returns many of the features and arrangements of the longer work.

The subject matter is divided three ways. Part I is devoted to the First Law of Thermodynamics, Part II to the Second Law, and Part III to applications of the principles and methods developed in the first two parts.

Sets of problems immediately follow more than half the articles in the book, and a list of general problems is included at the end of each of the chapters in Parts I and II. Answers are provided for about half the problems, thus increasing the value of the book as a source of self-study.

The book contains 280 pages and is priced at $4.50.

Mineral Wool Insulation Specifications & Standards

By the Industrial Mineral Fiber Institute, Inc.

The enlarged, up-to-date, fourth edition of the above-named specifier's handbook should prove a boon to buyers' of insulation in general and specifically to engineers, specification writers and contractors in properly selecting materials.

The book brings together 24 specifications and standards including 7 by the A.S.T.M., 2 by the U. S. Maritime Commission, 8 Federal Specifications and 3 commercial standards. Four Military Specifications on mineral wool blankets, blocks and boards, felts and insulating cement had not been issued at the time the previous edition of this handbook was published.

Each specification appears in the index to the handbook under type of mineral wool (there are eight basic types) and type of service (high or low temperature). Specifications by each of the five sources are placed together in tabbed sections. Helpful information in specifying and installing mineral wool can be drawn from data furnished on available product types, physical characteristics, standard dimensions, temperature use limits, recommended thickness, application techniques and test methods.

The book, bound with a tough, flexible cover, 6 in. by 9 in., sells for $3.50.